Turning Goals into Reality

Aerospace Technology Enterprise Annual Progress Report 2001

The Aerospace Technology Enterprise is an investment in America's future.

The future we see includes:

- A safer, cleaner world, in which the safety of air transportation is unquestioned and aircraft noise and emissions are dramatically reduced.

- A more open world, in which people everywhere can quickly, easily, and inexpensively travel wherever their lives lead them.

- An expanded world, in which space is fully opened for all human endeavor

- A world of opportunity, in which technologies developed through NASA's R&D investment are fully exploited for the benefit of our society.

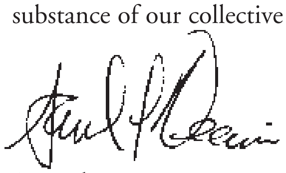
Letter from the Associate Administrator

I am proud to present the accomplishments of the Aerospace Technology Enterprise in this year's Annual Progress Report. The individuals at our NASA Research Centers and throughout the industry and academia who participate in our programs possess extraordinary talent, creativity and enthusiasm. These are the people who will make today's abstract visions and dreams possible.

Over the past year we have worked hard to forge ahead with bold new technologies — technologies that make considering the future of aviation and space transportation particularly exciting. Recently, we released the Aeronautics Blueprint to articulate how we can transform aviation, from eliminating aircraft noise in neighborhoods surrounding airports to expanding the capacity of the air transportation system to meet growing demand. The Blueprint consolidates our ideas and focuses our efforts on truly breakthrough technologies. With our history of success and the strength of our vision, I look forward to the future.

The accomplishments in this report represent only a step toward our vision, but they span an extraordinary breadth of technical disciplines and aerospace applications. The partnership between NASA, academia, industry and other government agencies that spearheaded these efforts is the strength upon which this vision will be realized.

I invite you to explore this report and the supporting website, so that you too may share in the excitement of making the substance of our collective imagination possible, of turning goals into reality.



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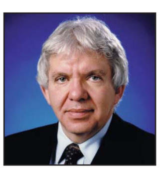
Associate Administrator for Aerospace Technology

Enterprise Executive Board



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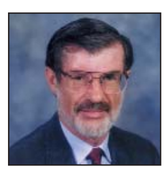

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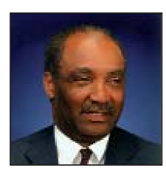

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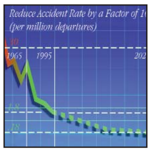
Goal One:

Revolutionize Aviation

Enable a safe, environmentally-friendly expansion of aviation. (Baseline: 1997)



Objective 1: Increase Safety

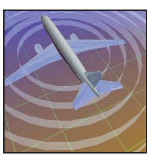
Make a safe air transportation system even safer

Reduce aviation's fatal accident rate by a factor of 5 within 10 years, and by a factor of 10 within 25 years.

Objective 2: Reduce Emissions

Protect local air quality and our global climate

Reduce NO_x emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NO_x as the baseline). Reduce CO_2 emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).



Objective 3: Reduce Noise

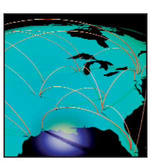
Reduce aircraft noise to benefit airport neighbors, the aviation industry, and travelers

Reduce the perceived noise levels of future aircraft by a factor of 2 (10 decibels) within 10 years and by a factor of 4 (20 decibels) within 25 years, using 1997 subsonic aircraft technology as the baseline.

Objective 4: Increase Capacity

Enable the movement of more air passengers with fewer delays

Double the capacity of the aviation system within 10 years and triple it within 25 years, based on 1997 levels.



Objective 5: Increase Mobility

Enable people to travel faster and farther, anywhere, anytime.

Reduce inter-city door-to-door transportation time by half in 10 years and by two-thirds in 25 years, and reduce long-haul transcontinental travel time by half within 25 years.

Goal Two:

Advance Space Transportation

Create a safe, affordable highway through the air and into space. (Baseline: 2000)

Objective 6: Mission Safety

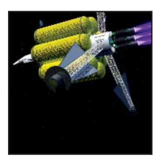
Radically improve the safety and reliability of space launch systems

Reduce the incidence of crew loss for a second generation Reusable Launch Vehicle (RLV) to 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1 million missions (an additional factor of 100) for a third generation RLV by 2025.

Objective 7: Mission Affordability:

Create an affordable highway to space

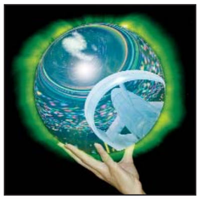
Reduce the cost of delivering a payload to Low-Earth Orbit (LEO) to $1000 per pound (a factor of 10) by 2010 and to $100 per pound (an additional factor of 10) by 2025. Reduce the cost of interorbital transfer by a factor of 10 within 15 years and by an additional factor of 10 by 2025.



Objective 8: Mission Reach:

Extend our reach in space with faster travel

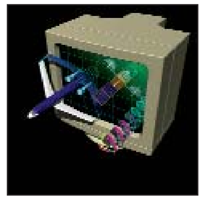
Reduce the time for planetary missions by a factor of 2 by 2015 and by a factor of 10 by 2025.



Goal Three:

Pioneer Technology Innovation

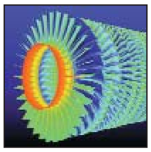
Enable a revolution in aerospace Systems.



Goal Four:

Commercialize Technology

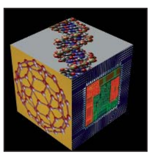
Extend the commercial application of NASA technology for economic benefit and improved quality of life.



Objective 9: Engineering Innovation

Develop advanced engineering tools, processes, and culture to enable rapid, high-confidence, and cost-efficient design of revolutionary systems

Within 10 years, demonstrate advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications; and within 25 years, demonstrate an integrated, high-confidence engineering environment that fully simulates advanced aerospace systems, their environments, and their missions.



Objective 10: Technology Innovation

Develop revolutionary technologies and technology solutions to enable fundamentally new aerospace system capabilities and missions

Within 10 years, integrate revolutionary technologies to explore fundamentally new aerospace system capabilities and missions; and within 25 years, demonstrate new aerospace capabilities and new mission concepts in flight.

Reporting on Enterprise Accomplishments

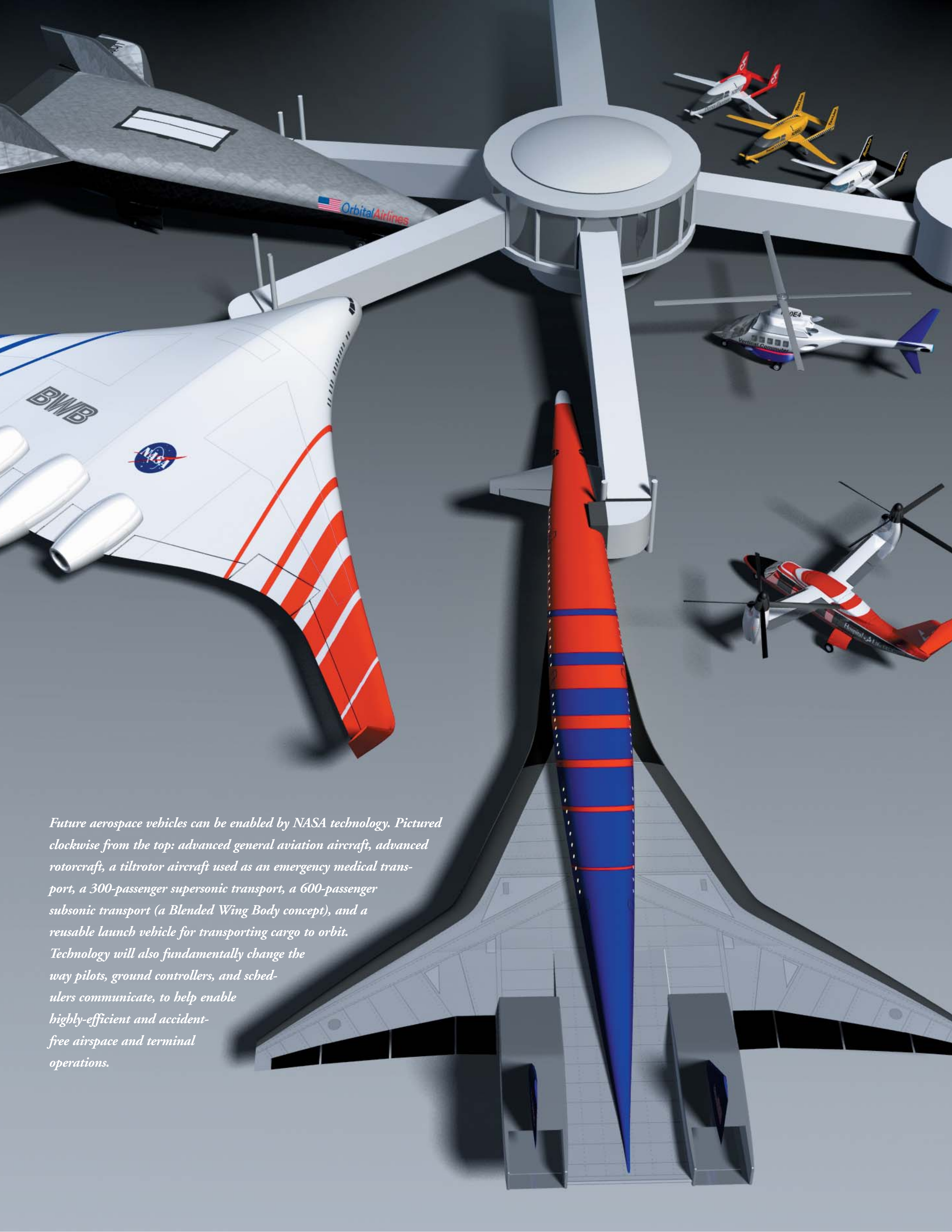
The Goals and Objectives reflect the real national needs that are aligned with our Enterprise mission. The Goals and Objectives “stretch” beyond what is possible today, forcing us to look beyond conventional concepts and evolutionary technologies. To succeed we must envision new systems and new vehicles enabled by revolutionary technologies.

This Annual Report highlights the accomplishments of the Aerospace Technology Enterprise for fiscal year 2001. The accomplishments represent milestones along a technology development path, and demonstrate a measure of progress toward the goals and objectives.

As assessment of overall progress is based upon a systems analysis of each Goal area. This integrated approach helps the Enterprise develop its long-term plans by identifying promising technologies and the research required to achieve them, measuring the extent to which current efforts contribute to those ends, and identifying high-leverage areas where further investments will help bridge gaps.

There is expanded information on the Web site (www.aerospace.nasa.gov) regarding the systems analyses, as well as other studies performed in support of Enterprise strategic planning, the development of our vision statements and strategic goals.

We encourage you to browse through the online version of this report. The Web site provides additional images, video clips, and information on the FY 2001 accomplishments, including links to related information found on homepages at our aerospace research centers.



Future aerospace vehicles can be enabled by NASA technology. Pictured clockwise from the top: advanced general aviation aircraft, advanced rotorcraft, a tiltrotor aircraft used as an emergency medical transport, a 300-passenger supersonic transport, a 600-passenger subsonic transport (a Blended Wing Body concept), and a reusable launch vehicle for transporting cargo to orbit. Technology will also fundamentally change the way pilots, ground controllers, and schedulers communicate, to help enable highly-efficient and accident-free airspace and terminal operations.

Goal One: Revolutionize Aviation

NASA's goal is to enable the safe, environmentally friendly expansion of aviation.

Creating the aviation system of the future to meet demands for growth will mean providing a more distributed, flexible, and adaptable network of airways. This growth must take place within the physical and environmental constraints of today's system, while meeting the evolving needs of air travel. The system of the future will continue to be international in scope, requiring close coordination across a global network. Advanced vehicles will operate in this new infrastructure and exploit cutting-edge capabilities such as "morphing" wings that optimize their shape for take-off, flight, and landing. Advances in information and sensor technologies will make air travel safer and more efficient. Air transportation will be easily accessible from urban, suburban, or rural communities, and will be affordable for all citizens. Airplanes will be cleaner, quieter, and faster. NASA aims to revolutionize aviation by delivering the long-term, high-payoff aerospace technologies, materials, and operations research needed for enabling these new vehicle and system capabilities.

The following pages report key accomplishments the Enterprise has achieved toward realizing this goal. Expanded write-ups and additional images, including videos, can be found on the supporting website.

Objective 1: Increase Safety

Make a safe air transportation system even safer.

Although the commercial aviation accident rate is very low, that rate has remained stubbornly constant for the past two decades. Even with the current low accident rate, the anticipated growth in commercial aviation would mean an accident frequency approaching a major accident every week. This could result in a perception that air travel has become unsafe. Our safety objective is intended to reduce the accident rate such that, even with traffic growth and an aging aircraft fleet, the frequency of future accidents will be reduced as compared with the baseline period of 1990 to 1996.

The following are examples of Fiscal Year 2001 research accomplishments that will contribute to aircraft and flight safety. For additional details, images, and movies see our online edition of this report at *www.aerospace.nasa.gov.*

Representative retrofit head-up and head-down display media devices used in the NASA Synthetic Vision Systems Project flight tests at Eagle Vail, Colorado.

1.1 The Future is Clear

Commercial and business aircraft in the future may be fitted with an advanced computer display that has the potential to make flying safer in bad weather and darkness. This technology is known as a synthetic vision system. Regardless of actual weather conditions, it shows the outside terrain and obstacles as if it were a sunny day.

NASA, an aircraft manufacturer, the FAA, and three major airlines tested the NASA-industry synthetic vision system concept at Eagle County Colorado Regional Airport, which is surrounded by rugged mountains. The pilots flew over 100 runway approaches in August and September of 2001. During the flights, pilots compared conventional displays and the concepts for the new synthetic vision display. The test flights gauged the effectiveness and ease of use of the new technology.

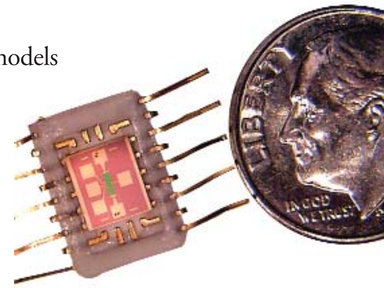
Early results indicate that the pilots were more aware of the outside terrain with the synthetic vision system than with conventional displays. The new computer instruments are designed be fitted into existing aircraft, as well as future aircraft designs. The ability to retrofit synthetic vision systems would allow current aircraft owners to use this lifesaving technology.

1.2 Alarm Over False Alarms

Commercial flights are plagued by a significant number of false fire alarms. Typically, smoke detectors mounted in under-floor cargo compartments mistake dust or mist for smoke. Aircrews often make emergency landings due to cockpit sensors mistakenly indicating fire in a remote compartment.

To prevent false alarms, researchers at the FAA and NASA are developing gas microsensors that can be arrayed throughout remote aircraft compartments. Universities are assisting in the effort by developing microsensors and signal interpretation software. Sandia National Laboratory is developing an analytic model to cover a wider range of fire situations.

This year, fire testing and analytic modeling was completed to verify the design concepts for cargo compartment fire sensors. Essentially, the sensors detect gases produced by fires (such as CO and CO_2), rather than just the smoke particulates from a fire. The FAA and NASA completed fire testing in the FAA's Cargo Compartment Fire Test Facility to help define the amounts and proportions of combustion gases that are produced during a cargo compartment fire. Sandia and NASA completed initial analytical models for both fire-gas and smoke transport through a virtual cargo compartment.



Sample tin oxide fire gas microsensor. Each microsensor can be part of a multi-sensor network distributed throughout aircraft or space vehicle compartments.

1.3 Stop Fueling the Fire

Reducing the flammability of aircraft fuels will make aircraft accidents more survivable. Crash impact survivors would be given precious time to escape the smoke and heat of post-crash fires that are fed by the aircraft's fuel. Researchers at NASA identified three technical approaches to reduce jet fuel flammability: adding surfactant additives, gelling agents, and making chemical composition changes to the fuel itself. Each of the approaches offers the promise of raising the jet fuel ignition threshold with minimal side effects on performance, practicality, and cost. Needless to say, a higher ignition threshold will make it harder for spilled fuel to catch fire. In addition, the increased resistance of jet fuel to unintentional ignition would provide better protection from in-flight fuel tank explosions.

Fire test in FAA Cargo Compartment Fire Test Facility

Through the use of jet fuel with a higher ignition threshold, crash impact survivors would have more time to find their way to emergency exists unimpeded by smoke and heat.

Over the next three years, NASA will be testing all three approaches at the recently completed test facility for fuel ignition located at the Glenn Research Center. The testing will be aimed at identifying the most promising concepts for further development.

1.4 Smart Planes Could Save Lives

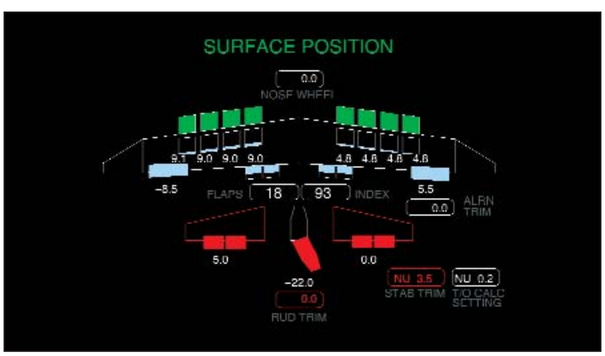
The Boeing and NASA joint Intelligent Flight Control (IFC) team developed a technological breakthrough in aircraft control, demonstrating significant flight safety advances in the face of potentially catastrophic in-flight failures. Major control surface failures negate the onboard flight control system's design assumptions, rendering the predefined fixed control system worthless.

The IFC team developed innovative neural network technologies that have been integrated with rapid prototyping tools for aircraft design, state-of-the-art control algorithms and propulsion control concepts. The neural adaptive flight control technology "learns" the new flight characteristics, onboard and in real-time, thereby helping the pilot to maintain or regain control. The end result is nothing short of saving the aircraft from a potentially catastrophic accident. The IFC technology correctly identifies and responds to changes in aircraft stability and control characteristics, and immediately adjusts to maintain the best possible flight performance during an unexpected failure.

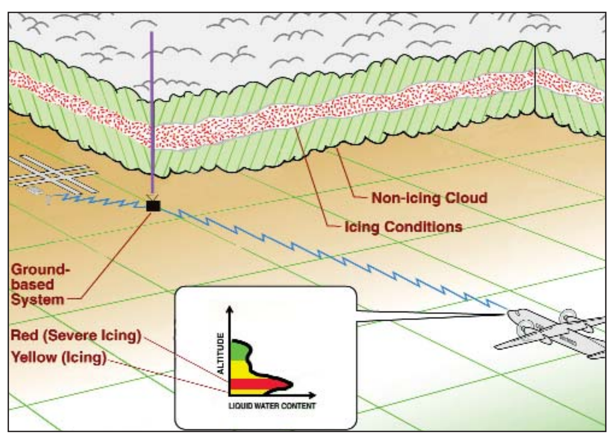
The Integrated Neural Flight and Propulsion Control (INFPCS) program was successfully demonstrated in a series of high-fidelity, full motion simulations over a range of failure scenarios (including hard-over rudder deflections and run-away stabilizers). Said NASA test pilot Jim Smolka, "This feels like a standard airplane, it doesn't feel like you have any (stabilizer) problems at all...much easier (to fly)...a big improvement."

1.5 Avoiding Icy Encounters

Eight existing technologies were evaluated for possible use as a ground-based remote-sensing system for icing conditions. The purpose of this research was to develop technology that would provide aircrews with information regarding icing at



Surface Position Indicator page for a simulated C-17 aircraft. Failed control surfaces are indicated in red, the surfaces at the limits of their travel are green and surfaces performing nominally are indicated in white. These indicators are very important to pilots for estimating their ability to control the plane.



Remote-sensing systems will allow pilots to "see" icing conditions before flying into a potentially dangerous condition.

lower altitudes, which is most problematic during take-off and landing. Six basic technologies and two hybrid technologies were ranked based upon technical value, technical maturity, and practicality. A hybrid system consisting of a profiling radiometer (capable of providing accurate air temperature profiles and the total amount of liquid water in the clouds) and a Ka-band cloud radar (to accurately define the location of the liquid water) scored the highest in this evaluation.

The final product, known as the NASA Icing Remote Sensing System (NIRSS), is being developed and tested in realistic airport environments to determine both its accuracy and how to best distribute to aircrews the information it generates. Currently, icing information is available only when encountered and reported by other pilots. If the NIRSS tests planned over the next three years are successful, it is possible that this system could be made available by 2007. It would provide aircrews with the altitudes and severity of icing conditions, thereby potentially avoiding the approximately 3 percent of commercial accidents that are attributable to ice and snow.[1]

1.6 Real-Time Check-ups for Planes

Aircraft accidents caused by equipment failure, which may account for approximately 23 percent of accidents today, might some day be prevented with the Aircraft Condition Analysis and Management System (ACAMS). NASA is developing this system collaboratively with ARINC, a company that specializes in providing transportation, communications, and systems engineering solutions for aviation. A future system would read data from sensors implanted throughout an aircraft's operating systems and physical structure. Any data that indicates malfunction or degrading performance would be used to alert aircrew or maintenance teams to take appropriate action.

During flight simulation in July 2001, our ACAMS technology prototype successfully identified landing gear brake faults that were intentionally set into the flight simulation program. In addition, it predicted how a small crack in an airframe structure would grow if no corrective action were taken. Crack growth prediction would allow

The Aircraft Condition Analysis and Management System (ACAMS) analyzes flight data from aircraft systems and structural components to predict potential failure conditions long before they would occur.

[1] *Boeing Commercial Jet airplane Accident Summary, June 2001, page 18, for years 1991-2000.*

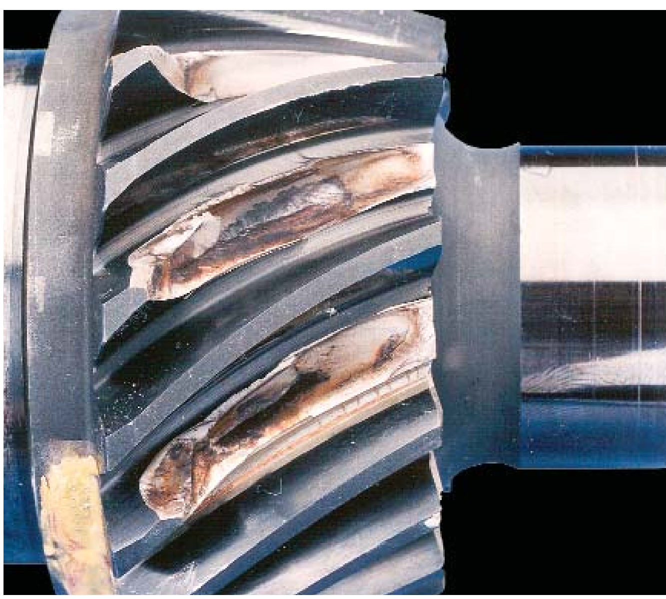
sufficient time for corrective action to be taken in order to avoid a potential accident. Further development of this technology is planned to include monitoring the health of landing gear, airframe, and propulsion systems. Researchers plan to have these technology capabilities ready for flight demonstration in 2003.

1.7 Ultra-safe Rotorcraft Gears

Gear failure and drivetrain failure, which causes a sudden failure of the rotors to turn, accounts for a significant portion (5 to 10 percent) of all rotorcraft accidents. The current trend of reducing gearbox weight is resulting in new lightweight gear designs that are more susceptible to rim fractures. This is a design weakness that will only exacerbate gear and drivetrain breakage. NASA's research effort in designs for stronger rotorcraft gears has resulted in a validated gear failure model. Design guidelines have been established, based on this model, that will lead to the design and production of ultra-safe gears. The model predicts three-dimensional crack propagation paths, and has been validated using the NASA Gear Fatigue Test Rig. The Test Rig allows researchers to systematically stress gears to see if they fail as calculated. Further research will produce the capability to develop a detailed gear design. The tools developed to determine three-dimensional crack propagation can then be used to analyze the final designs of a elicopter gearbox. This work represents a unique opportunity to accurately and efficiently assess and eliminate early in the design cycle the potential for catastrophic gear failure. This work will enable applications to take advantage of lightweight, thin-rimmed gears without compromising safety.

1.8 High Hopes for Higher Performance

Materials research is critical to enabling improvements in aircraft engine applications. Advanced high-strength, high-temperature materials are needed to increase the life of low-pressure turbine blades, which are located in one of the



Sample of a gear designed with defects to study how it fails. Shown are teeth broken off a spiral bevel gear due to repetitive stress delivered by the Gear Fatigue Test Rig.

hottest sections of an aircraft engine, just after the combustor. Materials researchers at NASA evaluated six factors most likely to determine if low-density, cast gamma-titanium aluminide (TiAl) alloys can be used in place of current nickel-based superalloys in low-pressure turbine blades. Factors evaluated include material fatigue properties (measures of the way materials fail), prior impact damage, casting defects, slight variations in chemical composition, and fretting (rubbing). Researchers investigated the fatigue properties of a new low-pressure turbine blade made completely of unaged materials.

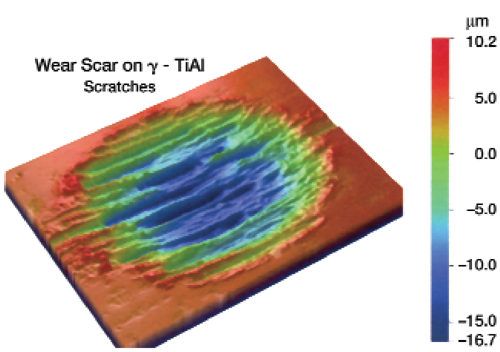
A 40 percent weight reduction in low-pressure turbine blades is possible by using TiAl instead of cast nickle-based superalloys. This relatively brittle intermetallic alloy can withstand typical in-service ballistic impacts to meet the blade design life. The study provided valuable design data, helping to remove a major barrier towards introducing TiAl alloys in aircraft engines.

1.9 The Smart Way to a Longer Life

Electronic controllers for current commercial aircraft engines provide high performance and operational stability. However, but the standard method of operation results in significant wear and tear on the engine, thereby shortening its "on-wing" life. In order to provide safe and reliable operation, the resulting engine wear and damage must be monitored closely and portions of the engine regularly replaced and rebuilt.

NASA, Scientific Monitoring, Inc., Honeywell Aerospace, GE Aircraft Engines, and Penn State University have been working toward a new control concept with "smart acceleration logic," as well as models to estimate and reduce engine damage. The resulting controller will significantly extend an engine's on-wing life with almost no impact on engine performance and operability.

Smart acceleration logic was successfully demonstrated on Honeywell's full-envelope, real-time simulator for the



Wear scar on a cast gamma-TiAl specimen showing the extent of damage after fretting with a typical superalloy pin.

Full Authority Digital Engine Control (FADEC) with intelligent life Extending Control

Teledyne Continental TFE731-20/40/60 engine. This hardware-in-the-loop demonstration is an important step in assuring that the Intelligent Life Extending Control (ILEC) logic is compatible with flight-grade engine controllers.

Bob McCarty, Senior Principal Engineer of Honeywell Engines said that, "Honeywell is very pleased with the ILEC simulations conducted in 2001. It's clear that developing the algorithms that predict engine hot-section damage can allow new control laws that will dramatically increase engine on-wing life."

1.10 Design Tool for Airport Safety

In order to test ways to improve runway safety FutureFlight Central (FFC), a virtual air traffic control tower, was used to recreate the complex work environment of Los Angeles International Airport (LAX). The objective of the study was to assess airport changes that could reduce the possibility of "runway incursions" a loss of separation between an aircraft on approach or take-off that results in a collision hazard with another aircraft or vehicle on the runway.

NASA conducted two simulation studies of LAX. First, a baseline study was performed to validate the accuracy of the facility's representation of LAX operations. Engineers created peak arrival and departure traffic scenarios that LAX controllers managed in real-time, demonstrating that FFC could sufficiently represent LAX. Controller surveys, aircraft surface movement metrics, and voice communication recordings were used to assess realism.

In the second simulation, LAX controllers tested alternatives to improve safety, including changes to surface management procedures, physical modifications to the

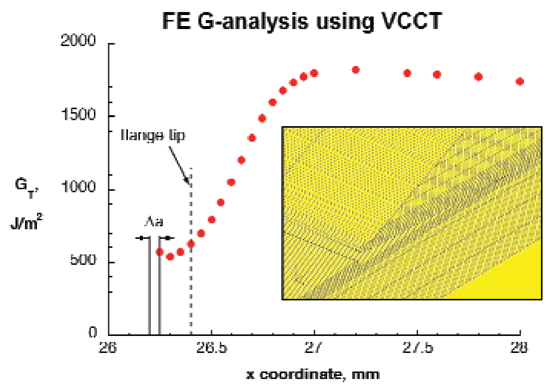
LAX air traffic controller manages virtual traffic in FutureFlight Central.

airport, and staffing changes in the tower. The results were compared against baseline measurements of airport efficiency, throughput, and safety. Based on the results, LAX management is proceeding with steps toward construction of a new taxiway.

1.11 Bending to Fatigue

The primary bending loads in aircraft fuselages are absorbed by the “longerons” that usually extend across several vertical points of support. The longerons are supplemented by other longitudinal members, called “stringers,” which are lighter in weight and are used more extensively than longerons. The vertical structural members are referred to as “bulkheads, frames, and formers.” In the future, aircraft fuselages may consist of a very thin skin bonded to reinforcing stringers, which would require new Federal Aviation Administration (FAA) design certification.

Because aircraft skin is designed to allow for minute movement called “buckling,” fatigue failure between the stringers and fuselage skin may occur. “Delamination” — the failure of the stringer-fuselage bonds — was studied using both a two-dimensional and three-dimensional computer analysis program. The much simpler two-dimensional computer analysis was determined to be as accurate a predictor of delamination as the three-dimensional version. The two-dimensional program was used to build a fatigue-life model. A scale model was tested, and the data was compared with the results from the fatigue-life model. The results from the scale-model test and the fatigue-life model were in accord. This work will contribute to a handbook used for composite materials certification.



Finite element (FE) analyses incorporating the damage observed at the flange tip of stringer pull-off specimens.

Objective 1: Increase Safety

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

Objective 2: Reduce Emissions

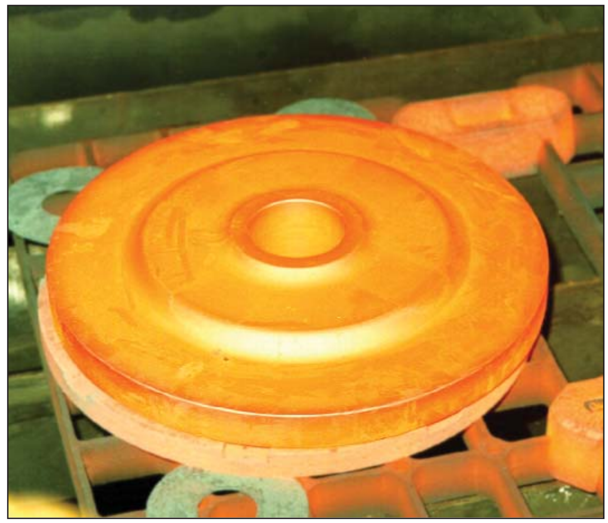
Protect local air quality and our global climate

The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection is addressing worldwide concerns about local air quality and climate change. Issued by the Intergovernmental Panel on Climate Change, the 1999 report "Aviation and the Global Atmosphere" projects that in 2050 aircraft carbon dioxide (CO_2) emissions will be up to 10 times greater than they were in 1992. Furthermore, in response to stringent ozone and particulate matter standards mandated by the U.S Clean Air Act, local authorities and environmental groups are demanding action from Federal agencies and air carriers. Their goal is the reduction of nitrogen oxide (NO_x) emissions, which are suspected of contributing to toxic ozone production, in addition to other pollutants. Because regulation will almost certainly constrain the growth of the aviation industry, improved technology will, in the long run, be the best way of curbing aircraft pollution.

The following Fiscal Year 2001 accomplishments in the area of emissions reduction research will contribute to the production of environmentally friendly aircraft.

2.1 New Disk Alloy Can Take the Heat

A team of materials researchers from NASA, GE Aircraft Engines, and Pratt & Whitney recently completed work on a revolutionary disk alloy for commercial and military engines. Disks are found in the rotating components of gas turbine engines; their function is to hold compressor and turbine blades in place. High strength materials that can withstand high temperatures are needed in turbine engines to increase engine efficiency, decrease weight, and reduce emissions.



Successfully Fabricated Boeing 737 Aircraft Size Disk Forgings from the New Alloy.

The new nickel-based powder superalloy, can withstand temperatures over 1300 degrees F, a 150 degree increase over disks currently in operation. With increased durability at high temperatures, engines can function at higher pressure ratios; this translates into increased fuel efficiency, lower fuel burn, and reduced aircraft emissions. Alternatively, engine manufacturers could use the new material in engines without increasing pressure ratios. This would allow increased time between required maintenance since operational life is estimated to be 30 times longer than current disks.

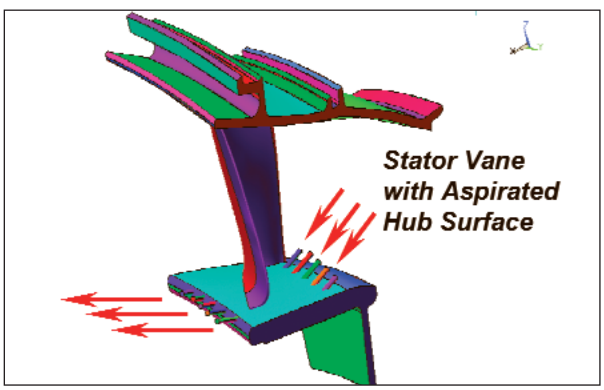
Over a million hours of testing has documented that this alloy has a balanced set of material properties that far exceeds current production material. Extensive microscopic analysis was also used to ensure the alloy's characteristics.

2.2 New Control for Engine Weight Loss

An important objective in designing propulsion systems is to decrease total weight while improving performance. For gas turbine engines, reducing the number of rotating blade rows (or "stages") by increasing the load on the blades can add up to significant weight savings.

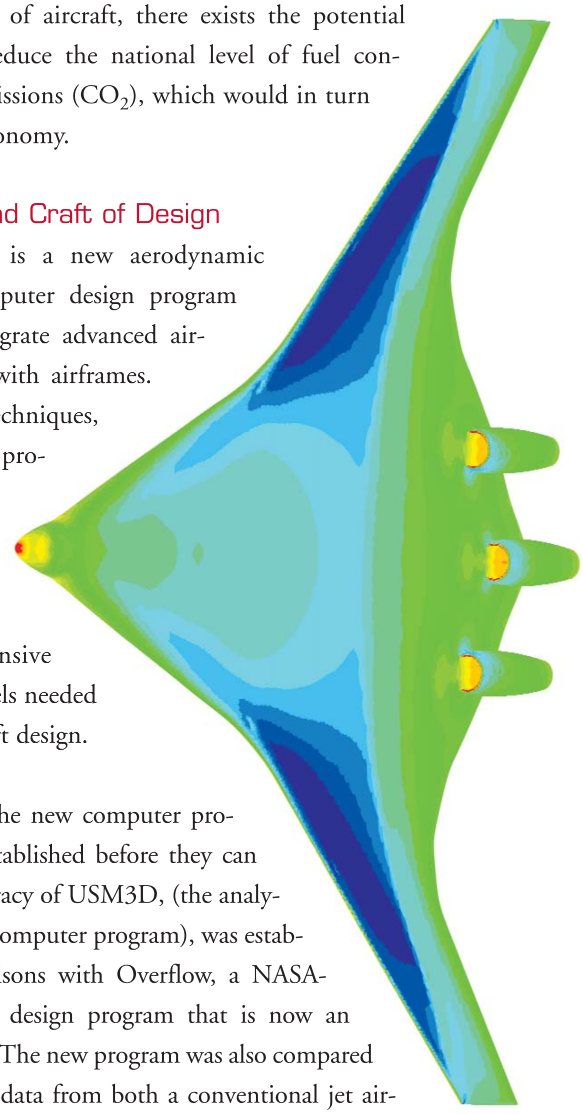
To demonstrate an enabling flow control concept, an aerodynamic and mechanical design was completed for a two-stage highly loaded low-pressure turbine (LPT). The flow control concept forces air through small holes in the base of the turbine blade to control airflow separation, thereby increasing the pressure (or load) that each blade can hold. New flow control approaches will enable future turbine engines to be designed with up to 50 percent fewer turbine stages and/or higher operating pressure ratios.

This study shows promise for eliminating one stage in LP turbine engines for regional class (50 passenger) applications. The resulting decrease in propulsion system weight will reduce an aircraft's fuel consumption. When multiplied over a fleet of aircraft, there exists the potential to significantly reduce the national level of fuel consumption and emissions (CO_2), which would in turn benefit the US economy.



Above: Air forced through small holes in the base of the turbine blade can control air flow separation. This new approach will give future engines multiple advantages. Right: Surface pressures computed on a Blended Wing Body aircraft using the new USM3D/CDISC design method.

2.3 The Art and Craft of Design



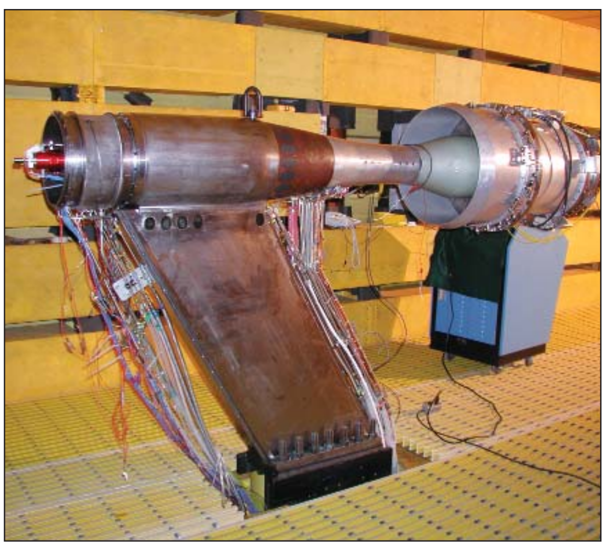
USM3D/CDISC is a new aerodynamic analysis and computer design program developed to integrate advanced aircraft jet engines with airframes. Based on novel techniques, the aircraft design program helps cut design time and costs by reducing the number of expensive wind tunnel models needed to refine an aircraft design.

The accuracy of the new computer programs must be established before they can be used. The accuracy of USM3D, (the analysis portion of the computer program), was established by comparisons with Overflow, a NASA-developed aircraft design program that is now an industry standard. The new program was also compared with wind tunnel data from both a conventional jet aircraft model and an advanced jet aircraft model, known as a blended-wing body (BWB).

The USM3D/ CDISC design program was then used to integrate advanced jet engines with both the conventional aircraft model and with the BWB aircraft model. The BWB aircraft was selected for wind tunnel testing in 2004 in order to validate the results from the computer design program. The BWB aircraft design has been proven extremely efficient when compared with conventional jet aircraft. NASA studies predict an almost 30 percent reduction in fuel burn and CO_2 emissions for the BWB.

2.4 Smoothing Wakes Saves Weight (A technical tongue twister!)

Computational fluid dynamics (CFD) has been a valuable tool in the design of aerodynamic systems. The "Fan Blade Trailing-Edge Blowing" concept was selected for testing based on a CFD simulation. The design was developed to meet goals for reduced CO_2 and noise production. The testing of this concept met the minimum success criteria of achieving partial span filling of fan rotor wake with less than one-percent mass flow, with no increase in noise.



Supersonic cruise 2-stage fan hardware is installed with a drive rig for performance testing in the GRC 9x15 Low Speed Wind Tunnel.

The idea behind the "Fan Blade Trailing-Edge Blowing" concept was to reduce the magnitude of the downstream wakes of the fan blades, using the fan blade trailing-edge bleed flow to fill the wakes. This concept allows the rotor/stator spacing in the fan stage to be decreased significantly, which in turn reduces noise and saves weight. Filling in the wakes also reduces the strength of the fan's unsteady aerodynamic downstream loads, which has the potential benefit of increasing the fatigue life of the structure.

2.5 New Technologies for Cleaner Engines

During FY 2001, industry and NASA design teams developed conceptual models of advanced engines for each class of commercial aircraft. NASA and industry partners will prototype and test many of the component technologies in these designs, so that manufacturers can complete the technology development needed for production engines. Using technology now under development in NASA's Ultra-Efficient Engine Technology program, these advanced engines could be available for production as early as 2010.

System analyses indicate that all of the engine designs meet or exceed the goals for a 70 percent NO_x reduction (from the 1996 baseline) and 15 percent CO_2 reduction for subsonic transports, and 8 percent CO_2 reduction for the supersonic business jet. Achieving both NO_x and CO_2 goals in the same engine is especially challenging, as the design for one goal typically compromises the design required for the other.

The government role in exploring high-risk/high-payoff technologies is of critical importance, particularly in areas that benefit the public good, as corporate research is driven by near-term market forces. During FY 2000, NASA, in partnership with the aircraft engine industry, demonstrated technology that would reduce NO_x emissions by half. Without that demonstration, this technology would not yet be incorporated into production engines as it is today.

2.6 Smart Wings May Revolutionize Flying

Aircraft designers have continuously searched for ways to improve both the efficiency and performance of aircraft. Typically, aircraft wings are designed to be most efficient at a single flight condition, but suffer performance penalties at other flight conditions. These penalties may be reduced through the judicious positioning of "conventional" leading- and trailing-edge hinged control surfaces. Since the 1980's, researchers have investigated the use of fully-integrated adaptive material actuator systems (so-called "smart technologies") for performance-enhancing shape control. The Smart Wing program is one such effort where DARPA, AFRL, NASA, and the Northrop Grumman Corporation are working together to develop and demonstrate these technologies.

As part of the Smart Wing program, researchers performed wind-tunnel tests at NASA to demonstrate a new technology that may revolutionize how unmanned combat air vehicles fly. Actuator arms driven by "smart" motors were integrated into the trailing-edge control surface on a wind-tunnel model of an unmanned combat air vehicle. If used in conjunction with an appropriate control law, these actuators could potentially allow the wing to respond to changing aerodynamic conditions, which would permit the vehicle to fly more efficiently by reducing drag and fuel consumption. In the future, the results of the demonstration will be analyzed and documented by the Northrop Grumman Corporation.

The DARPA/AFRL/NASA/Northrop Grumman Smart Wing Phase 2 Model mounted in the NASA Langley Transonic Dynamics Tunnel test section.

Objective 2: Reduce Emissions

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

Objective 3: Reduce Noise

Reduce aircraft noise to benefit airport neighbors, the aviation industry, and travelers.

Although aircraft noise has dropped dramatically in the last 30 years, the number of airports worldwide affected by local noise restrictions has grown significantly. The impact of noise from aircraft operations continues to constrain the air transportation system due to curfews, noise budgets, and slot restrictions. The public clearly wants to reduce the impact of noise their communities. But in the absence of appropriate technology, the public's expectations can only be met through constraints on airport construction. Increasingly stringent standards governing aircraft noise mandated in 2000 the elimination of Stage 2 airplanes. Stage 3 standards are now in effect and Stage 4 standards are looming on the horizon.[2] The long-term 20-decibel objective for noise reduction will, in most cases, contain objectionable aircraft noise within airport boundaries (55 Day Night Level contour).

The following examples of Fiscal Year 2001 accomplishments in the area of noise reduction research will contribute to the production of environmentally friendly aircraft.

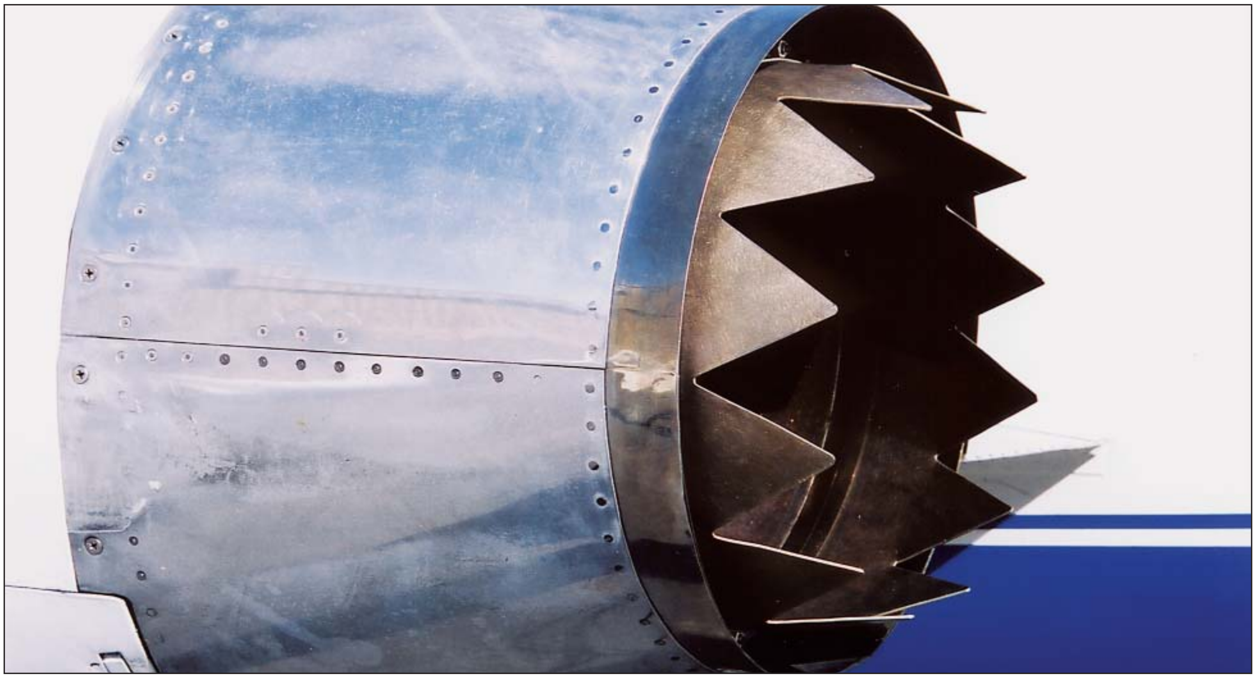
[2] *Stage 2, Stage 3, and Stage 4 are the noise stringency standards for jet-powered aircraft, set by the FAA for aircraft operating in U.S. airspace. These standards are negotiated in an international context through the International Civil Aviation Organization (ICAO). Stage 2 compliant aircraft completed their operational phase-out in December 2000. Stage 3 standards are more stringent and are now in effect throughout the fleet. Stage 4 are the standards that are currently being debated by the ICAO.*

3.1 Putting a New Nozzle on Noise

In a collaborative effort between NASA and Honeywell, the noise reduction benefits of "scarfed" inlets, a variable-area exhaust nozzles, and several different "chevron" nozzle concepts were successfully flight-tested on Honeywell's Falcon 20 testbed aircraft. Chevron nozzles were also tested on Glenn Research Center's Lear Jet.

These important technologies are being incorporated into commercial aircraft engines. The GE CF34-8 engine, to be certified in 2002, will be the first engine to include nozzle chevrons (Aviation Week, July 9, 2001, p.50). The technology will also be used on regional jets including the Bombardier CRJ900, Embraer ERJ-170 and the

The noise reduction technology has been flight demonstrated by Glenn Research Center on NASA's Lear 25 turbojet aircraft. There is a potential of extending this technology to higher velocity jet exhausts for military applications.



The 12-point chevron nozzle (shown) was flightdemonstrated by NASA on its Lear 25 turbojet aircraft. There is a potential of extending this technology to higher velocity jet exhausts for military applications.

Fairchild Dornier 728JET. Additionally, Boeing recently flight-tested a B777 with a series of engine noise reduction technologies in addition to nozzle chevrons. Company representatives indicate that these technologies are needed to assure that Boeing aircraft will meet anticipated noise standards for London Heathrow Airport so that they may operate without restriction.

The noise reduction technologies already demonstrated will begin to improve the quality of life for those who live and work near airports. In addition, these advances will improve the competitiveness of the domestic aerospace industry by assuring that U.S.-built engines and aircraft continue to meet international noise standards.

3.2 Measuring Against the Best

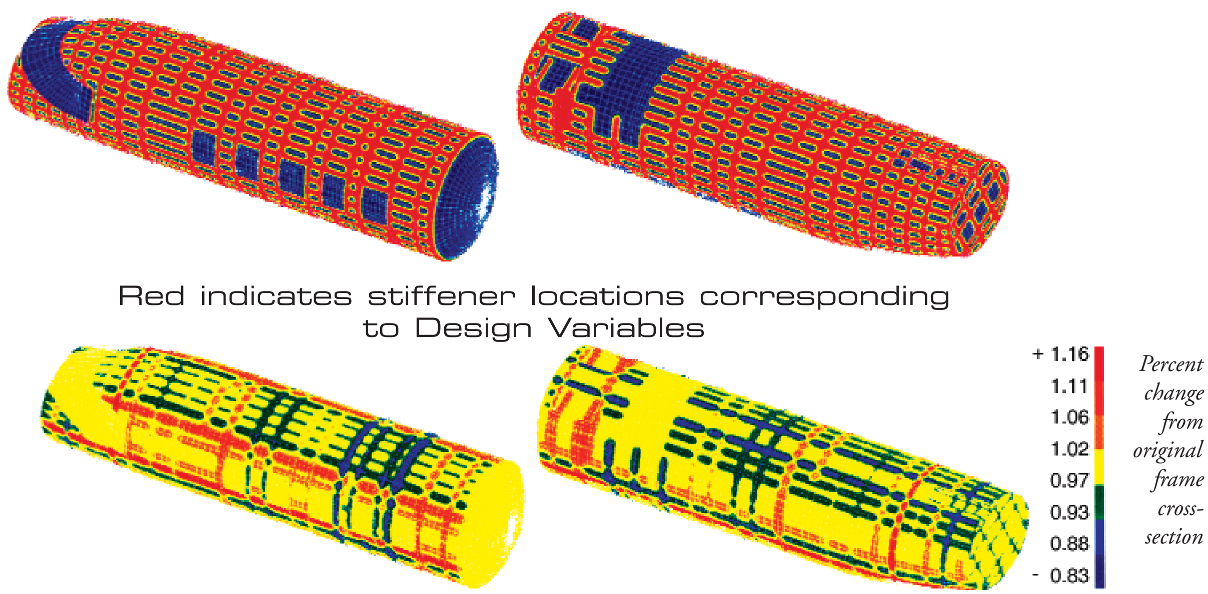
In FY'01, NASA researchers selected the baseline aircraft against which all technologies developed in the Quiet Aircraft Technology (QAT) program will be measured. The "best in fleet" aircraft for 1997 were chosen as the baseline — a Boeing 777 to represent a long-range twin, and a Bombardier CRJ to represent a regional jet. Two very different size aircraft were chosen because technologies that are beneficial when applied to large aircraft sometimes are not applicable to smaller aircraft.

The methodology chosen to evaluate the technologies will be a "matrix" of measures for noise reduction potential and technology maturity level. This matrix is similar to that used for the recently concluded Noise Reduction Project. Over the five years of the QAT program, two formal technology assessments will be conducted to determine the progress of the QAT program by evaluating QAT technologies relative to the baselines. A formal interim assessment will be conducted in FY'03, and a final assessment in FY'05. Informal assessments will also be conducted in FY'02 and FY'04.

3.3 Controlling Cabin Noise

The safety and comfort of passengers and crew is significantly affected by interior noise. In FY 01, NASA researchers successfully demonstrated that aircraft interior noise can be reduced by 6 dBA with active and passive noise reduction technologies relative to 1992 technology. These technologies attack aircraft noise as it is transmitted (via structural vibrations) through the fuselage, and reduce noise levels without the weight penalty of conventional, passive interior noise treatments.

For propeller aircraft, the dominant source of interior noise is the interaction of air with the propeller blades. On a Cessna 182, NASA researchers tested an active structural-acoustic control system array composed of credit-card sized force actuators, a controller and a microphone. In tandem with vibration absorbers, the control system reduced total interior noise by 13 dB. Researchers also demonstrated that optimizing the



Red elements in images on the top row define the structural frames of a Cessna Citation III cabin in a top and bottom view. At bottom, frame elements optimized for noise are shown. Yellow indicates no change in dimension, red indicates frame members that were increased 16 percent in crossection, and those shown in blue were decreased by 16 percent over the production structure. This provided 6 dB noise reduction with no additional weight.

structural design of an aircraft can reduce noise. The cross-sectional properties (width, thickness, shape) of a Cessna Citation III frame were changed to reduce engine tone penetration while maintaining the same weight. A 6 dB reduction was achieved at the six passenger locations.

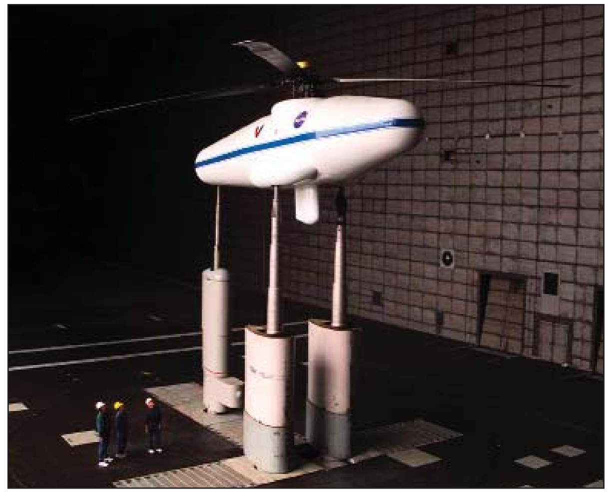
Interior noise will increase in future aircraft with reduced structural weight, so there is a continuing need for new interior noise reduction technologies.

3.4 A Revolutionary Concept Makes Helicopters Quieter and Smoother

Wind tunnel tests of a highly advanced control technology showed that changing the pitch angle of each individual helicopter rotor blade lowered rotor-generated noise and vibration by 75 percent. The testing of the Individual Blade Control (IBC) concept was done as part of the Black Hawk rotor test in the NASA 80- by 120-Foot Wind Tunnel.

The IBC technology works by replacing the rotating blade pitch control links with hydraulic actuators. These actuators are capable of superimposing up to ±6.0° of blade pitch motion over the normal flight controls.

At high-noise test conditions simulating descent flight and landing, noise reductions of over 12 dB (75 percent) were obtained using ±3.0° of IBC input. At forward flight conditions having high vibration, only ±1.0° of IBC eliminated up to 75 percent of the total vibration. These considerable noise and vibration reductions indicate that the IBC technology holds much promise in developing runway independent aircraft (RIA) for use in congested urban areas. The IBC research program is being conducted under a Space Act agreement between NASA Ames/Army, Sikorsky Aircraft Corp., and ZF Luftfahrttechnik GmbH.



Large Rotor Test Apparatus with rotor installed in 80-by 120-Foot Wind Tunnel.

Objective 3: Reduce Noise

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

Objective 4: Increase Capacity[3]

Enable the movement of more air passengers with fewer delays.

Another NASA goal is to safely move significantly more aircraft through the aviation system with less delay. Concepts for alternative vehicle and improved infrastructure must be developed interdependently to ensure that they can operate together successfully and increase the capacity of the National Airspace System (NAS). Partnerships with the FAA, U.S. air carriers, manufacturers, and operators are essential. The FAA's effort to modernize the NAS and transition the Nation to a "Free Flight" architecture [4] over the next 5 to 10 years provides a major opportunity to integrate NASA technologies into commercial air travel. Research on concepts and technologies to increase airspace system throughput will be a priority for the foreseeable future.

The following are a sampling of NASA accomplishments in FY 2001 that will contribute to the nation's air system capacity.

4.1 Finding the Alternatives

One way to solve the problem of delays at major airports is to significantly reduce the number of aircraft needing runways for takeoff and landing. Aircraft that fly short routes, often with relatively few passengers, take up valuable runway space. NASA's Aviation Systems Capacity program investigated the possibility of using tiltrotor aircraft for short haul and commuter flights. The tiltrotor can land in a very small area like a helicopter, yet fly like a conventional plane while in cruise mode. The versatility of tiltrotor aircraft permits short haul/commuter flights that would free up runway space for larger aircraft. Civil tiltrotor offers a unique opportunity to create a new aircraft market while reducing flight delays.

Tiltrotor simulation scenarios at San Francisco International Airport included flights in highly constrained airspace, engine failures during landing and takeoff, and adverse weather conditions.

In FY 2001, the Short Haul Civil Tiltrotor (SHCT) project was successfully concluded. This NASA task focused on developing the ability to fly predictable, precise, and safe low-noise landing approaches. By overcoming the environmental and safety challenges facing this new class

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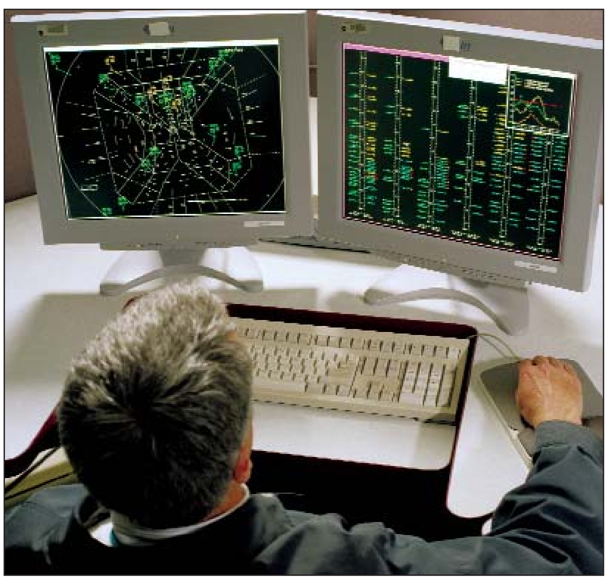
[3] *The factors for capacity are based on predicted demand growth in revenue passenger miles (RPMs). The capacity and delay baseline reflects the proportion of good and adverse weather conditions that typically occur on an annual basis.*

[4] *A concept that moves the NAS from a centralized command-and-control system between pilots and air traffic controllers to a distributed system that allows pilots, whenever practical, to choose their own route and file a flight plan that follows the most efficient and economical route*

of aircraft, significant progress has been made toward doubling the capacity of the airspace system and reducing inter-city, door-to-door transportation time by half within the next 10 years.

4.2 Arrivals in Real Time

The Collaborative Arrival Planner (CAP) is an extension of NASA's Center TRACON Automation System (CTAS). CTAS is a set of software decision support tools that provides computer-generated advisories to assist Center and TRACON traffic management coordinators and air traffic controllers in the efficient management of air traffic. While CTAS was designed to help FAA personnel, CAP expands the capabilities of CTAS by sharing Traffic Management Advisor (TMA) information with air carriers.



CAP is the first system to allow real-time air traffic management information to be shared with air carriers. It is currently installed at American Airlines Systems Operations Control Center, Fort Worth, Texas and Delta Airlines Airport Coordination Center, Dallas-Fort Worth Airport.

The CAP system augments air carrier operations in both Airline Operational Control and Ramp Tower settings. CAP does this by providing accurate time-of-arrival predictions and situational awareness of Center and TRACON operations. CAP allows airlines to see in real-time aircraft position, speed data, and the assigned landing runway. Airlines also have access to air traffic management information, including current and planned runway configuration and airport arrival rate. In cooperation with the FAA and air carriers, CAP display systems were installed at the American Airlines System Operations Control facility in Fort Worth, TX and the Delta Air Lines Airport Coordination Center at Dallas-Fort Worth Airport. Based on the success of this tool at American and Delta Airlines, it is expected that CAP will benefit airlines that have hubs located at sites where CTAS operates.

4.3 "Direct To" the Fastest Route

In today's air traffic control system, aircraft fly on fixed airways. Air traffic controllers have limited automation to help identify opportunities for more efficient flight routes. Direct-To (D2) is a decision support tool for en route radar controllers that analyzes air traffic data nationwide every 6 seconds in order to identify opportunities for shorter, time-saving flight routes, while calculating the effects of wind and the possibility of conflicts. Within a few seconds, a controller can bring up a graphic computer display of a D2 route, activate a fast-loop conflict analysis, modify the route if necessary, and input a D2 flight plan amendment. All of this can be accomplished by an air traffic controller with just 2 or 3 mouse clicks, without turning away from the traffic display.

En route sector configuration during the D2 field test at the Fort Worth Air Route Traffic Control Center (D2 display shown at right).

In FY 2001, a team of 9 experienced controllers at Fort Worth Center participated in an operational evaluation of the D2 tool. Controllers evaluated 3,204 D2 routes and issued 1,198 D2 flight plan amendments to revenue flights during 136 sector-hours of operational testing. NASA is currently working with the FAA and its contractors to implement D2 functionality on the controller's primary radar display. If this tool were fully operational at Fort Worth Center, it could result in a savings of 900 flying minutes per day or $9,000,000 per year.

4.4 Driving Communications Upward

The aviation industry continues to grow at a rapid pace, as the number of passengers is expected to increase by 5 percent per year over the next decade. The movement of information is essential for implementing capacity and safety improvements. Current aviation communications technologies are woefully inadequate to deal with the requirements of a high capacity, information intensive, future National Airspace System. To address this concern, the Mobile Aero Satcom Terminal was developed and evaluated, under NASA's Aviation System Capacity Program using a mobile ground vehicle.

The purpose of the Mobile Aero Satcom Terminal was to demonstrate and evaluate satellite communications technologies that could provide a high-capacity communications link with aircraft. The ground testing provided integration and evaluation activities to verify the terminal's performance. The unit was examined further during a series of DC-8 flight trials in cooperation with NASA's Information Technology Program. Under extreme bank/roll/heading conditions, high transmission (256 Kbps) and reception (2.180 Mbps) data rates were maintained at speeds of 360 knots and altitudes up to 40,000 feet. Simultaneously, communication network applications were demonstrated, including Internet browsing and web serving, e-mail, and the transmission of live video.

The Mobile Aero Satcom Terminal in a ground mobile configuration, demonstrating that satellite communications technologies can provide a high capacity communications link to a moving vehicle.

4.5 Validating a Sound Database

NASA's Short Haul Civil Tiltrotor (SHCT) project is an example of what can be achieved when government agencies and industry work together towards a common goal. Throughout the history of the SHCT endeavor, NASA has partnered with the FAA and industry to develop efficient, low noise, rotor designs. Mutual respect and a "can do" attitude have allowed this team of scientists to obtain results beyond their original expectations. By working together to reduce aircraft noise, this alliance has changed the future of rotorcraft design.

An important element of the SHCT project was the development and validation of a noise prediction system that would accurately determine the sound levels produced by tiltrotors while still in the design phase. This permitted noise to be included as a design parameter. The team developed a database of low-noise rotor designs, and used it as a basis for developing efficient, quiet tiltrotors and flight profiles. The result is the Tiltrotor Aeroacoustic Code, the first tiltrotor aircraft noise prediction system. Using piloted simulations and XV-15 flight tests of selected designs, the team established and validated a design database for civil tiltrotor transport aircraft.

Objective 4: Increase Capacity

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

Wind tunnel and flight tests were conducted to investigate and demonstrate advanced civil tiltrotor technologies aimed at predicting and reducing tiltrotor noise.

The world's first civil tiltrotor, the BA609.

Objective 5: Increase Mobility

Enable people to travel faster and farther, anywhere, anytime.

Improving mobility within the U.S. by reducing travel time for both short and long journeys requires a wide range of innovations and improvements. To reduce travel times into and out of every community, NASA is working on methods to integrate small aircraft and all public-use landing facilities into the national air transportation system. This will require improvements both to aircraft and to the network of small airports. For long journeys, affordable supersonic travel will be essential, but the technological challenges are significant. NASA is working to resolve specific technology problems such as sonic booms, engine noise, and emissions. NASA will also assess new vehicle design concepts, develop advanced mobility concepts such as the tiltrotor, and fully integrate them within the overarching aviation system. All these will contribute to reductions in travel time.

5.1. Accomplishments Aplenty, Successful Completion of AGATE

The Advanced General Aviation Transport Experiments (AGATE) project was an alliance of government, industry and the academic community, brought together with the goal of revitalizing domestic General Aviation (GA) technology deployment. The creation of the AGATE Alliance as part of the NASA AGATE project was a key contributing factor to the industry's recovery.

AGATE glass cockpit technologies, demonstrated at AirVenture 2001 on the Highway-In-The-Sky demonstration aircraft. Intuitive displays allow a "low-time" pilot to operate the aircraft in a complex environment safely and proficiently with less initial and recurrent training.

The AGATE cockpit provides the operator a graphically intuitive interface with all of the information required for safe, efficient transportation. The left panel provides the aircraft's operating state, including heading and altitude information. The center panel provides a moving map with information along the flight path such as navigation, terrain, weather and other aircraft. The right panel is available for a second pilot or can be used to obtain consumer information such as fuel, rental car, dining or lodging availability through an in-flight Internet datalink.

In 2001, AGATE successfully demonstrated an advanced, integrated cockpit system architecture. This architecture includes the "Highways In The Sky" or HITS operating system, a low cost AGATE Databus, Simplified Flight Controls, an AutoLand system, a low cost Air Data and Attitude Heading and Reference System (ADAHRS), and an Airborne Computer Resource (ACR).

The flight demonstration of the HITS operating system aboard a Lancair Columbia 400 at AirVenture 2001 in Oshkosh, Wisconsin, represents the completion of the AGATE technology program. It presented an integrated small aircraft transportation vehicle that flight-validated a majority of key technologies developed in AGATE. The products developed in AGATE have provided the aircraft technology foundation for the Small Aircraft Transportation System (SATS) project, which focuses on applying these airborne technologies to advances in operating capabilities throughout the National Airspace System.

5.2 Make the Most of What We Have

The Small Aircraft Transportation System (SATS) is a vision for the expansion and integration of general aviation aircraft into the nation's airways to more effectively use the 5,000+ public use airports. This expansion would increase access to smaller communities and improve the transportation of people, services, and cargo.

The FAA and NASA have initiated an integrated system safety plan, a software-independent verification and validation process, and a certification plan. The two agencies have also established initial concepts for operations, a systems engineering management plan, system requirements, and a risk management plan for SATS.

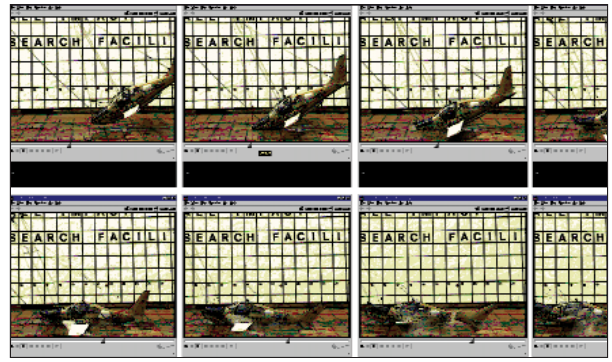
A major accomplishment for the SATS program was completing a solicitation to establish a broad consortium of state aviation and transportation authorities, private sector companies, end user groups, non-profit organizations, and universities. An initial set of four SATSLab teams were selected through a competitive process (Southeast SATSLab, Virginia SATSLab, North Carolina/ Upper Great Plains SATSLab, and the Maryland SATSLab). These teams will define the operational and functional requirements for the technologies to be evaluated, and will also support the planning of integrated technology, flight validations in 2004, and the proof-of-concept flight demonstrations in 2005.

5.3 Guidelines for Crash Survivability Published

To achieve the AGATE Alliance vision for affordable, safe, 21st century inter-city transportation using smaller aircraft and smaller airports, innovation in crashworthiness technology is vital. One of the AGATE goals was to make general aviation aircraft crash survivability equal to or better than highway auto accidents.

To meet the challenges associated with survivability and injury mitigation for General Aviation aircraft accidents, the AGATE Crashworthiness Team collaborated to create an approach to design, manufacture, and certify an impenetrable occupant fuselage.

The AGATE alliance organized industry-wide design guidelines and standards for crash safety, and produced the first approaches to integrated crashworthy designs for composite structures. As a result, the concept of an impenetrable occupant cabin is being evaluated for future aircraft.



Drop Test: Velocity = 94.7 ft/sec, q = 30°(nose down)

More than twelve design guidelines and technical documents were published on such crashworthiness topics as Inflatable Restraints, Computer Modeling, Energy-Absorbing Subfloors, Seat Certification, Aircraft Airbag Sensors, Energy Absorption Characteristics of Composite Sandwich Panels, Thermoplastic Energy-Absorbing Subfloor Structures, Shoulder Belt Pre-Tensioners, and Head Injury Risks. In addition, one of the AGATE members, Simula, provided a short course for industry on these crashworthiness design, testing, and certification methods. Through these publications and the short course, new industry-wide crash safety standards for small aircraft were deployed.

5.4 New Circulars Straighten Path to Certification

The AIR AGATE Team, led by the FAA Small Airplane Directorate and the AGATE Alliance, provided visionary leadership in the creation of regulatory policy and the revision of FAA certification methods for new technologies developed in the AGATE project. In this industry sector, successful technology transfer requires broad industry collaboration with the FAA on certification.

Hot section radial foil air bearing

Working with AGATE Alliance members, the FAA revised its guidance materials for certifying cockpit technologies. The resulting policy supports industry application of commercial-off-the-shelf computer technologies for higher reliability, increased performance, and lower cost avionics that will revolutionize flight training and safety. Two new advisory circulars (AC23.1309 and AC23.1311) are now recognized as significant recent regulatory advancements in aircraft technology deployment.

The team also streamlined the composite materials qualification process, reducing by more than 75 percent both the cost and time required to develop new airframes. The AGATE Alliance members agreed to share proprietary composite materials data, which resulted in a materials standards handbook that is now recognized as the FAA guideline for composite design. The resulting materials certification procedures have reduced the cost of airframe manufacturing by at least 25 percent.

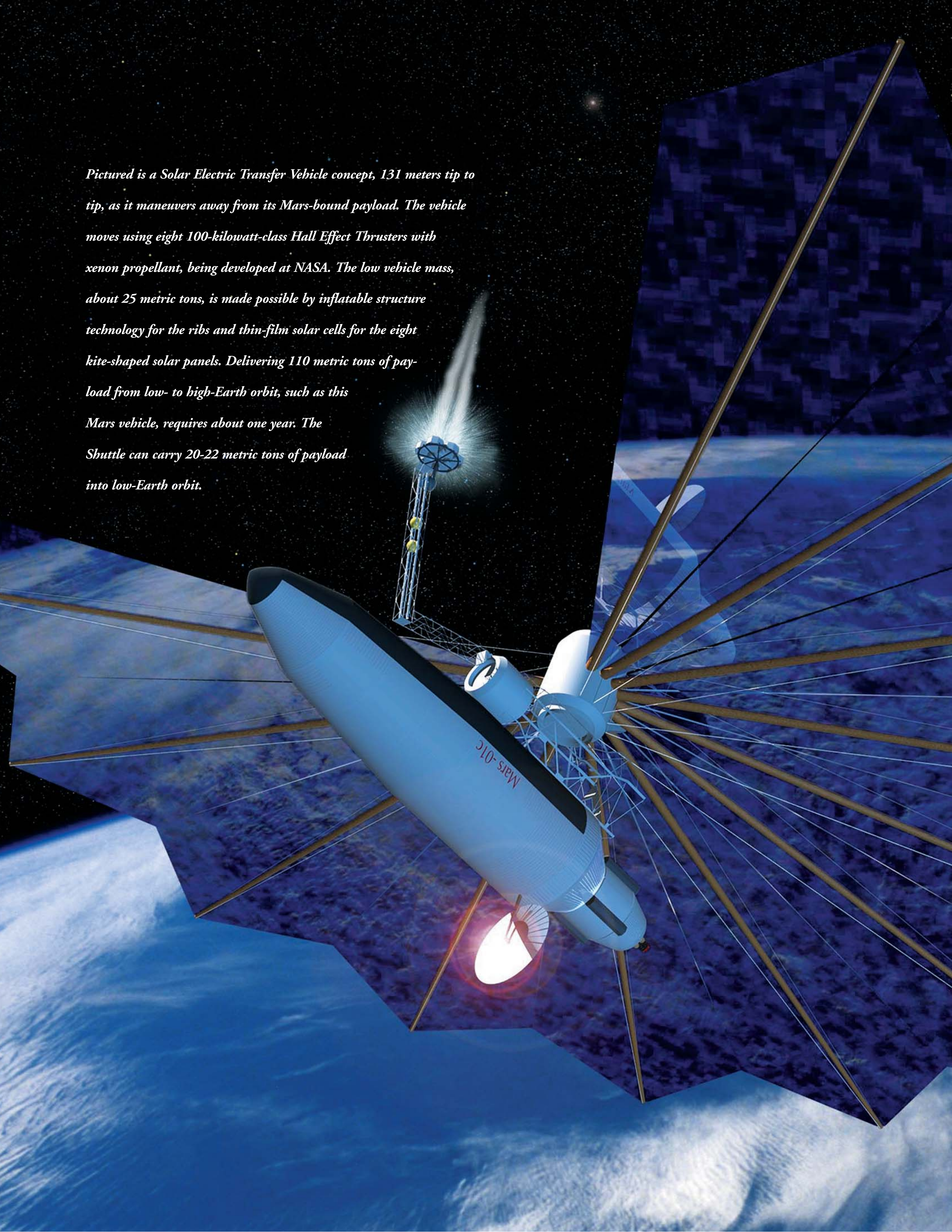
5.5 Big Savings from a Small Package

NASA researchers successfully tested oil-free bearings through the range of high-speed, sustained-load, and elevated-temperature conditions seen in the core of a gas turbine engine. A NASA-patented coating technology allowed the bearings to operate as hot as 1200 degrees F. This test of a prototype radial foil air bearing is leading the way to a completely oil-free version of the Williams International EJ-22 turbine engine.

Oil-free foil air bearing technology eliminates the need for the oil lubrication systems required by rolling element bearings currently used in gas turbine engines. Oil-free technology has significant benefits, including the reduction of engine weight by 15 percent, power density improvements of 20 percent in very high-speed operations, and the reduction of engine maintenance costs by 50 percent. Studies have shown that for a 50-passenger regional jet, Oil-free technology can reduce Direct Operating Cost (DOC) by 8 percent.

Objective 5: Increase Mobility

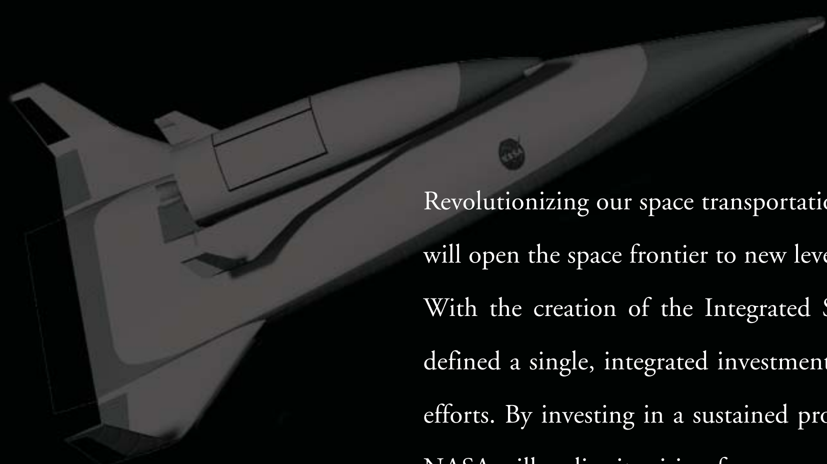
The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.



Pictured is a Solar Electric Transfer Vehicle concept, 131 meters tip to tip, as it maneuvers away from its Mars-bound payload. The vehicle moves using eight 100-kilowatt-class Hall Effect Thrusters with xenon propellant, being developed at NASA. The low vehicle mass, about 25 metric tons, is made possible by inflatable structure technology for the ribs and thin-film solar cells for the eight kite-shaped solar panels. Delivering 110 metric tons of payload from low- to high-Earth orbit, such as this Mars vehicle, requires about one year. The Shuttle can carry 20-22 metric tons of payload into low-Earth orbit.

Goal Two: Advance Space Transportation

NASA's goal is to create a safe, affordable highway through the air and into space.



Revolutionizing our space transportation system in terms of cost, reliability and safety, will open the space frontier to new levels of exploration and commercial development. With the creation of the Integrated Space Transportation Plan (ISTP), the Agency defined a single, integrated investment strategy for all its diverse space transportation efforts. By investing in a sustained progression of research and technology initiatives, NASA will realize its vision for spacecraft surmount the Earth-to-orbit challenge.

The following pages report key accomplishments the Enterprise has achieved toward realizing this goal. Expanded write-ups and additional images, including videos, can be found on the supporting website.

Objective 6: Mission Safety

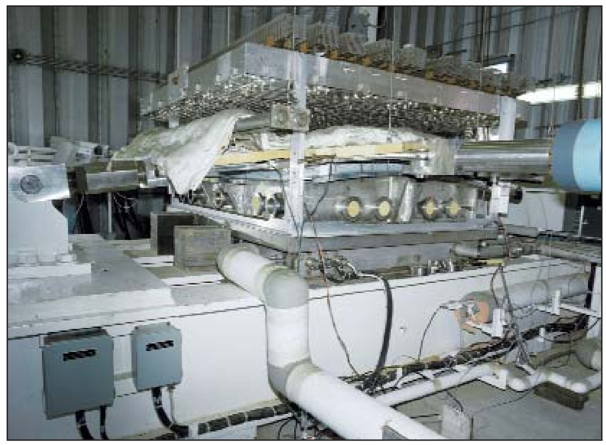
Radically improve the safety and reliability of space launch systems.

One long-term goal NASA hopes to achieve is developing an advanced space transportation system that decreases the probability of crew loss from 1 in 250 flights (the current Space Shuttle rate), to one loss in 10,000 flights. A significant increase in the performance margin of launch systems is fundamental to achieving this objective. NASA is working to reduce the risk of crew loss through improving vehicle safety and reliability. One strategy is to create vehicle launch systems with fewer parts and more robust subsystems. Integrating intelligence into vehicle systems will result in better vehicle health management and self-repair. The development of tools that will enable end-to-end computer design and testing of an entire vehicle, including life cycle risk assessment, will dramatically increase mission safety. If space launch and travel is made safe, it will enhance development of the commercial space sector and help make space accessible to all.

6.1 Under Pressure for Faster Results

Cryogenic propellant tanks compose about 35 percent of a reusable launch vehicle's dry weight. To achieve the weight savings necessary to reduce the cost of sending payloads into orbit, future reusable launch vehicles may require cryogenic propellant tanks made of Polymeric Matrix Composite (PMC). The design of tanks manufactured using PMC will be critical in ensuring safe and reliable operations. The robustness of the material and structural design must be verified under mission profile conditions in order to certify that the cryogenic propellant tank operates safely.

To save time and ensure safety, NASA researchers have developed protocols and accelerated thermal/mechanical test methods to screen candidate materials and structural designs for cryogenic fuel tank applications. Examples include the uni-axial cyclic tension test and the Cryogenic Pressure Box Facility. These test methods screen the material's mechanical and physical properties across a range of conditions, including temperature change (-423 degrees F to 1000°F), pressure range (0 to 45 psig), and mechanical loading (uni-axial and bi-axial). The ability to more quickly select candidate materials and structural designs will reduce the overall time and cost of developing cryogenic propellant tanks for advanced space transportation vehicles.



Corner view of a curved stainless steel checkout test panel in the Cryogenic Pressure Box Test Facility with the heater array in place.

6.2 NASA's Space Launch Initiative—New Capabilities…New Horizons

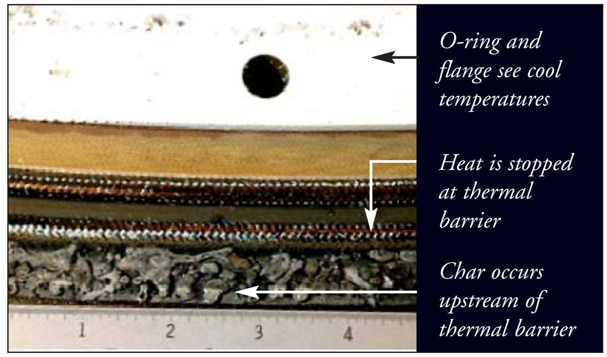
Begun in February 2001, the goal of the Space Launch Initiative (SLI) is to design a new space transportation system that will enable significant near-term improvements in America's space capabilities. SLI marked the first major milestone of 2001, with the awarding of 22 prime contracts and the formation of a NASA-wide team to manage all technology areas of the program. Team SLI brought together some of the Nation's most talented scientists and engineers, while making available NASA's extensive research, test, development, and evaluation facilities, many of which are one of a kind.

By improving space transportation safety, reliability, and cost effectiveness, the Agency can begin to use the Space Station as a cutting-edge scientific laboratory. SLI is reducing the business and technical risks of building a space transportation system for America's 21st century civil, commercial and defense missions. Team SLI is gaining momentum, progressing toward the mid-decade selection of an optimal space transportation system for America by mid decade.

6.3 Keeping Rocket Motors Safe

A new, highly-reliable thermal barrier structural seal has been developed for several critical nozzle joints on the Space Shuttle Solid Rocket Motor. The new thermal barrier seal represents a significant improvement over current technology and will dramatically improve the reliability and structural integrity of critical solid rocket motor nozzle joints.

The new thermal barrier is made of a unique braided carbon fiber-based material designed to withstand the high temperature environment (5500 degrees F) inside a solid rocket motor (SRM). NASA engineers conducted basic research to develop the new seal concept and to determine the optimum material and geometric design. The new seal concept was



Post-test photograph showing hot gas effects upstream of thermal barrier and no heat effects downstream. Metal flange and O-rings beneath flange remained in like-new condition.

shown to have a "burn through" rate greater than three times the total burn duration of the Shuttle SRM.

The re-designed SRM joints are scheduled to enter service on a Space Shuttle mission in late 2003.

Objective 6: Mission Safety

6.1 Under Pressure for Faster Results
6.2 NASA's Space Launch Initiative—New Capabilities...New Horizons
6.3 Keeping Rocket Motors Safe
6.4 X-34 Status for 2001 (Web Only)

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

Objective 7: Mission Affordability

Create an affordable highway to space

Achieving this objective will enable payload delivery to low-earth orbit at a cost of $100 per pound, a dramatic reduction from the approximately $10,000 per pound it costs today. NASA also seeks to reduce the overall cost of delivering payloads to a higher orbit. The agency must endeavor to make payload delivery relatively inexpensive without compromising safety or reliability — all are essential characteristics of a dynamic, productive space transport system. Meeting these goals will require improved reusable launch vehicles; advanced launch systems and operations; and improved propulsion, materials, and structures for durable, lightweight in-space transportation vehicles. By developing additional capabilities for medium and heavy payloads (including systems to transfer payloads between Earth orbits), NASA will create a true "Highway to Space."

7.1 Better Simulations for Better Rockets

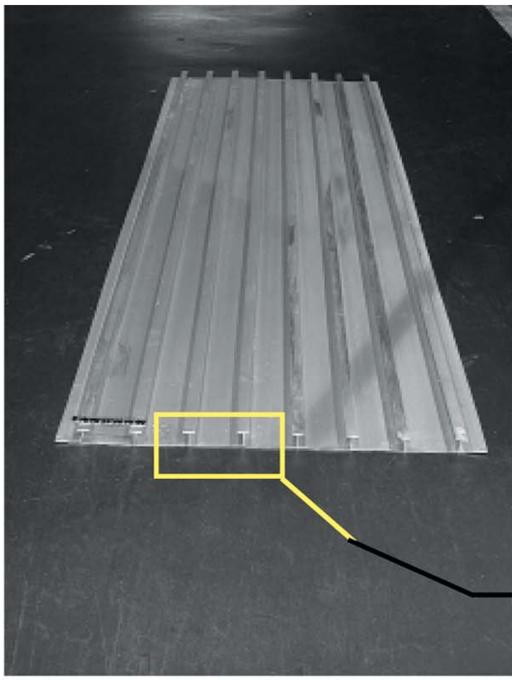
Phase 1 modifications to the Numerical Propulsion Simulation System (NPSS) that allow analysis of both rocket and rocket-based combined cycle (RBCC) propulsion systems have been completed. Modifications to NPSS were accomplished by adding additional modules (such as the RBCC isolator module), resulting in the new RBCC capability. These modifications also improved rocket engine capability by greatly increasing the number of different rocket cycles that can be simulated.

The RBCC representation provides a simulation capability not previously known to exist: a coupled primary flow path and feed. The ability to close couple both the feed system and the primary flow path systems results in a greatly reduced analysis time by providing a single, more comprehensive simulation of the RBCC system. The coupling of the primary flow path and the fuel feed system inside one simulation, the addition of thermal (heat transfer) modeling capabilities, and the expansion of the fuel properties to higher temperatures and pressures resulted in a significantly enhanced simulation capability.

7.2 Being Thin Skinned Has Advantages

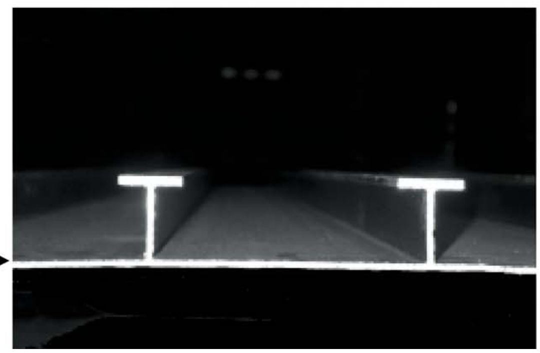
Near-net shape extrusions of lightweight aluminum-lithium (Al-Li) Russain alloy 1441 are attractive candidates for future aircraft fuselage skin. The Al-Li alloy was extruded into near-net thin-walled panels, approximately 0.070 inch, which is representative of the thickness of aircraft fuselage skin. To help prevent warping during the extrusion process, conventional Al and Al-Li alloy extrusions typically have more than twice this wall thickness. Extrusions with thinner walls will require less machining to produce a finished fuselage panel, and will have the potential to lower aircraft weight. The reduced machining will also result in lower production costs and less material wasted during manufacturing.

Four panels of the integrally stiffened thin-walled Al-Li alloy 1441 extrusion were successfully fabricated by the All-Russian Institute of Aviation Materials (VIAM) and delivered to NASA. The panels were approximately 80 inches long by 38 inches wide, with 1.5-inch tall T-stiffeners spaced approximately 4.75 inches apart. The successful fabrication of these extrusions demonstrated the potential this technology has for fabricating low-cost, lightweight aircraft and launch vehicle structures.



Panel extruded as externally-stiffened cylinder, then split and flattened

- Wall thickness: 0.070 inch
- Stiffener spacing: 4.75 inches
- Stiffener height: 1.5 inches



Future plans include characterizing the microstructure and mechanical properties of the extrusion. Small extrusion specimens will be used to evaluate crack behavior, especially near the integral stiffeners. Large integrally stiffened panels will be tested to determine crack arrest capability.

7.3 A (Composite) Key to Success

It is critical that the airframe of any future vehicle be optimized for safety, cost, performance, and weight — a classic aerospace dilemma. New airframe technologies will allow for the fabrication of lightweight metallic and composite structures, which means that wings, fuselages, and tanks can be optimzed in terms of both weight and strength. Vehicle aerodynamics and aerothermodynamics must also be considered since they influence payload size and the temperatures to which the vehicle can be subjected.

The first sub-scale cryogenic tank built of a composite material compatible with liquid oxygen has successfully completed the initial cycles of cryogenic, or very low temperature, testing. Composites are seen as one of the key components for decreasing the weight of future launch vehicles, which in turn means reducing the overall cost of a space launch. In this case, using the composite tank represents an 18 percent weight savings over the use of a similarly constructed metal tank. Composites may also be found in advanced thermal protection systems capable of surviving subsonic flights through rain and fog, thereby increasing the safety of the vehicle.

7.4 X-37 Flight Demonstrator

All major structural components of the X-37 flight demonstrator have been delivered to Palmdale, CA, where they will be assembled. The experimental craft could be used to test airframe, propulsion, and operation technologies in real-world environments; a scale-model prototype of the X-37 (called the X-40A) has successfully completed a series of drop-tests in the initial atmospheric phase.

7.5 Future Vehicle Health Management

Building on the success of the Boeing 777 and Joint Strike Fighter design process, the Space Launch Initiative is developing diagnostic software for automatic health status through every phase of operations- including pre-flight, in-flight, and post-flight. Integrated Vehicle Health Management (IVHM) systems will collect and process information about the health of a system to enable informed decisions and actions by vehicle crews, maintenance personnel, and automated ground systems. Using advanced microchip technology will allow a new level of monitoring, providing real-time status of operating systems. Program goals are to provide an advanced health management architecture that integrates information from individual subsystems and components to determine the overall state of the vehicle while in operation for real-time fault detection, isolation, and recovery.

7.6 Mishap on Hyper-X Mach 7 Flight

The X-43A was designed to be the first scramjet-powered vehicle capable of attaining speeds as high as Mach 10. The June 2, 2001 mission, the first in a series of three, was lost moments after the X-43A and its Pegasus launch vehicle were released from the wing of the NASA B-52 carrier aircraft.

Following launch vehicle ignition, the combined launch vehicle and X-43A experienced structural failure, resulting in a deviation from the intended flight path. The mission was then deliberately terminated with an explosive charge, causing the X-43A and Pegasus to fall into a cleared Naval sea range off the coast of California. A Mishap Investigation Board (MIB) was immediately formed and is conducting a thorough review of the failure. The findings are expected to be released at the beginning of CY 2002, and will be addressed prior to scheduling the next X-43 flight (which won't occur prior to the beginning of FY 2003).

Objective 7: Mission Affordability

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

NASA DFRC B-52 Takes Off With X-43A/Launch Vehicle Stack Under Its Wing for the Attempted First Flight on June 2, 2001.

Objective 8: Mission Reach

Extend our reach in space with faster travel.

In order to reduce travel times, this objective aims to develop lightweight, rapid space propulsion systems. Technology focus areas include small interplanetary travel systems and "breakthrough" propulsion technologies that allow missions to reach other stars within the span of a human life.

8.1 Iridium Rocket Chamber

NASA researchers developed and perfected an iridium-coated rhenium (Ir/Re) material system for radiation-cooled rockets. This marks the first major advance in on-board chemical propulsion for satellites in 30 years. It is likely that Ir/Re chambers will be the new standard for radiation-cooled rocket engines using storable propellants. The new Ir/Re chambers operate at 2200 degrees Centigrade, increasing the operating temperature by 900 degrees Centigrade over current state-of-the-art chamber materials. This increase in operating temperature allows a significant reduction of fuel film cooling in bipropellant engines, with a corresponding increase in combustion efficiency. NASA has worked with commercial rocket engine manufacturers to develop and insert this technology into the design cycle.

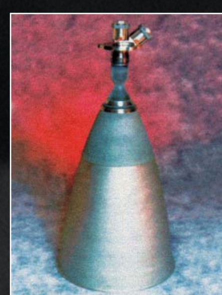
One manufacturer, General Dynamics (GD) Space Systems Division, has successfully integrated Ir/Re chambers into 100-lbf engines, providing a 22 second (7 percent) increase in specific impulse (Isp) and orbital velocity over current propulsion systems. Specifically, the material has enabled an Isp of 330 seconds, compared to 308 seconds for General Dynamic's state-of-the-art engines. This has a substantial impact (15-20 percent increase) on science and/or communications payload at the final destination orbit or depending on the spacecraft, a mass savings of up to 55 kg for a geosynchronous communications satellite.

Objective 8: Mission Reach

8.1 Iridium Rocket Chamber

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

High Performance Apogee Thruster (HiPAT)



based on an iridium-coated rhenium material system, marks the first major advance in on-baord chemical propulsion for satellites in 30 years.

Science and technology continue to evolve, and new theories and physical phenomena are emerging that have profound implications for air and space transportation. This image captures the human drive to imagine bold new possibilities, and our capacity for technical and scientific innovation. Shown is a spacecraft entering a wormhole for interstellar travel that may one day become possible.

Goal Three: Pioneer Technology Innovation

NASA's goal is to enable a revolution in aerospace systems.

In order to develop the aerospace systems of the future, revolutionary approaches to system design and technology will be necessary. Innovation means pursuing technology fields that are in their infancy today, developing the knowledge bases necessary to design radically new aerospace systems, to perform efficient, high-confidence design and development of revolutionary vehicles. These challenges are intensified by the unquestionable demand for safety in an environment of increasing complexity for aerospace systems. The goal to Pioneer Technology Innovation is unique in that it focuses on broad, crosscutting innovations critical to a number of NASA missions and to the aerospace industry in general.

The following pages report key accomplishments the Enterprise has achieved toward realizing this goal. Expanded write-ups and additional images, including videos, can be found on the supporting website.

Objective 9: Engineering Innovation

Enable rapid, dependable, and cost-efficient design of revolutionary systems.

Assuring safety, dependability, quick turn-around times, and efficiency in developing revolutionary aerospace systems must all become benchmarks of our future engineering culture. To meet these needs, NASA will develop the tools and systems architecture to provide an intuitive, trustworthy, comprehensively-networked engineering design environment. This interactive network will foster the creative power of development teams. Engineers and technologists, in collaboration with all mission or product team members, will redefine the way new vehicles or systems are developed. They will have the ability to accurately understand all key aspects of their systems, operating environments, and mission before committing to a single piece of hardware or software.

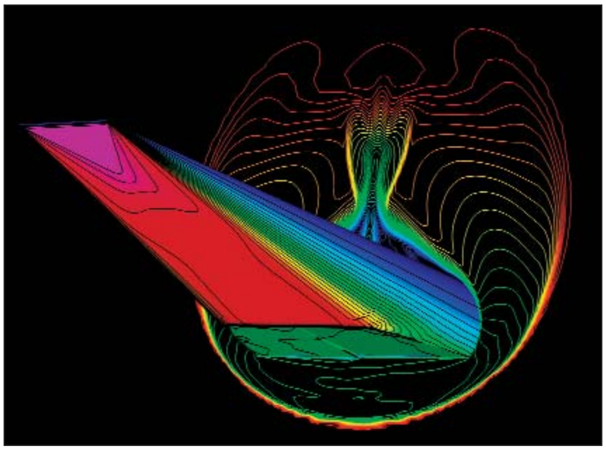
9.1 Stalling No Longer a Costly Problem

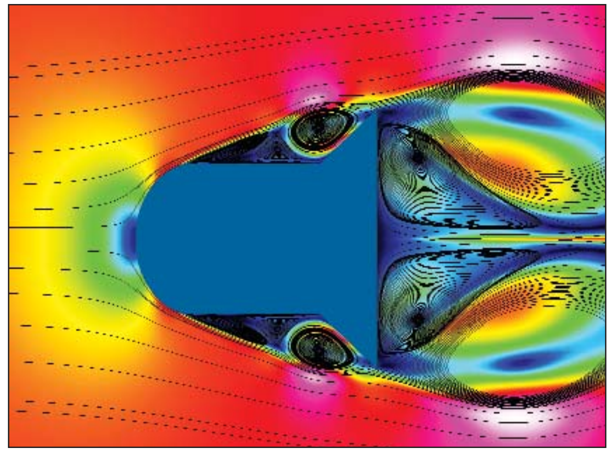
Historically, flight testing was the only reliable method of finding solutions to the problem of abrupt wing stall (AWS), or sudden loss of lift during transonic flights. Abrupt stall can occur due to relatively small changes in angle of attack, and causes rolling motions because of the significant loss of lift in one wing.

NASA is developing wind tunnel tests and computational fluid dynamics methods that focus on finding design characteristics that cause abrupt wing stall during the early stages of aircraft design. These new methods will help to insure that a potential problem with abrupt wing stall is identified and eliminated before flight testing is started, saving both time and money. For example, the F/A-18E was forced into one and a half years of developmental flight tests to solve its AWS problem. Researchers had to evaluate over 100 different configurations in over 500 flight tests, at a cost of tens of millions of dollars.

Working jointly with the U.S. Navy and the U.S. Air Force, NASA developed validated methods for identifying abrupt wing stall. NASA is continuing to complete design guidelines and procedures for preventing abrupt wing stall and other uncontrolled flight motions for high performance aircraft.

F/A-18E 9 percent scale model undergoing free-to-roll tests in the Transonic Dynamics Tunnel to study abrupt wing stall behavior.





Illustrations of recent design synthesis and analysis applications. (Left) SHARP-enhanced reentry vehicle concept (hypersonic)—Scott Lawrence, APS (Right) Mars Sample Return vehicle concept (subsonic)—Scott Lawrence, APS

9.2 Tools for New Generation of Design

By combining state-of-the-art Information Technology (IT) with high-fidelity engineering analysis, this project is prototyping new multi-disciplinary design synthesis and analysis techniques for Reusable Launch Vehicles (RLVs).

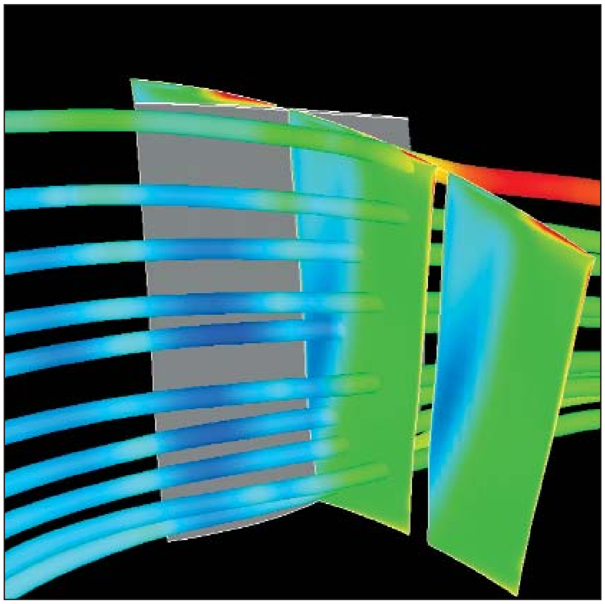
Since engineering analyses are inherently complex and multi-disciplinary, flexible strategies for coupling the tools must be considered. New approaches for efficiently running these coupled, resource-intensive analyses in distributed, heterogeneous computing environments (like the NASA Information Power Grid) are under development. The IT components of this methodology include the creation of novel software agents for controlling analysis processes. The vehicle engineering disciplines include structural analyses, external aerothermodynamics, flight simulation, heat transfer, and trajectory optimization.

Ultimately, improvements are expected in crew safety and project risk due to an increased understanding of vehicle tradeoffs and limitations. Information and knowledge technologies will play an ever-increasing role in ensuring the efficient creation and collaborative distribution of design data, and the capture of both design intent and rationale.

Projects supported in the past year by this work include the Second Generation suite of launch vehicles, new Crew Transfer Vehicle studies, the Boeing/NASA X-37, the Mars Sample Return design effort, and upgraded Space Shuttle configurations.

9.3 Codes to Compress Time

Researchers at the Glenn Research Center achieved sizable reductions in compressor and combustor simulation time. The National Combustor Code (NCC) and the Average Passage NASA (APNASA) code were combined in parallel and optimized in order to achieve a full engine simulation overnight. A full 3D combustion simulation of 1.3 million elements was achieved in only 1.9 hours using 256 computer processors. This represents an improvement of 1,617



Simulation of the GE90 High Pressure Compressor showing total temperature of streamtubes in rotor 2.

times relative to 1992. Researchers also achieved a full compressor simulation in 2.5 hours, which is 2,400 times faster than what could be achieved only a decade ago. This simulation of a General Electric compressor used 504 processors.

The NCC and APNASA codes can be used to evaluate new combustor and compressor design concepts. These codes can be integrated into a design system to provide fast turnaround and high-fidelity analysis of an engine early in its design phase. The improved quality of prediction provided by these codes can result in improved confidence in the design and a reduction of the number of required hardware builds and tests. These improvements to NCC and APNASA will contribute to: (1) significant reduction in aircraft engine design time and cost, and (2) reduced aircraft engine emissions.

9.4 Room with a View

To ensure that NASA's space transportation investments are sound and, Marshall Space Flight Center has developed the Advanced Engineering Environment (AEE). The AEE is equipped with the latest analytical integration tools, and is being used to assess data generated by Space Launch Institute (SLI) activities performed across the country. The AEE eliminates the need for engineers and analysts to travel between Centers and cities for collaborative work, thereby reducing program costs and allowing milestones to be reached more efficiently.

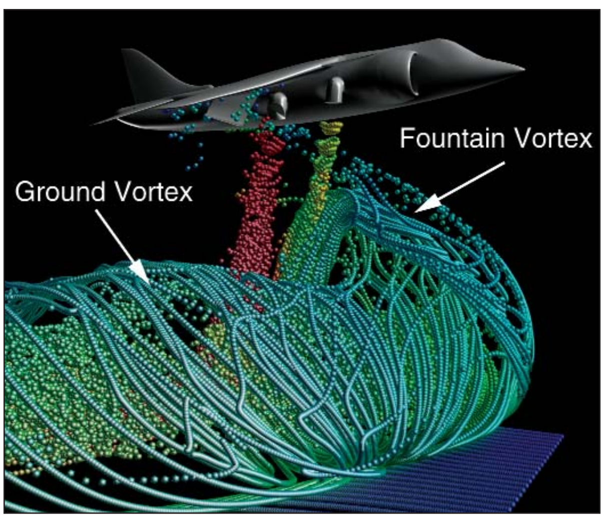
This state-of-the-art computing environment facilitates assessment and verification of architecture concepts, technology improvements, and support requirements. Technical progress is measured regularly for cost accountability and disciplined innovation. In this way, Team SLI will deliver detailed plans for a new capability that meets America's needs. The plans will be backed up by a portfolio of advanced aerospace technologies that are validated through design, hardware testing, and proven business models. The emphasis is on the integration and interdependence of the activities of each of the stakeholders, minimizing isolation and fragmentation of effort.

9.5 Powerful Database Will Help Maintain Control

The Harrier aircraft is capable of vertical and short-field take-off and landing (V/STOL) by directing its four exhaust nozzles downward. Computational Fluid Dynamics (CFD) can be used to generate a database of computer simulations to explore the handling qualities and flight operations safety of powered-lift aircraft, such as the Harrier, in close proximity to the ground.

There is a concern that the engine inlet may ingest hot jet gasses, causing a rapid reduction in powered lift. High-speed jet flows along the ground can also cause low pressures on the underside of the vehicle, resulting in a "suck-down" effect. Researchers were able to generate 35 high-fidelity viscous flow solutions in one week by using 952 Silicon Graphics Origin 3000 processors. This solution database was further expanded to over 2500 cases using a monotone interpolation procedure, from which static handling qualities can be inferred.

The figure shows time-varying exhaust nozzle flow, with red corresponding to hot temperatures and blue to cooler temperatures. Resulting ground and jet-fountain vortices are also indicated in the figure. A 15-fold reduction in time to solution for a "worst case" was achieved over the past 17 months using process automation and parallel computing.



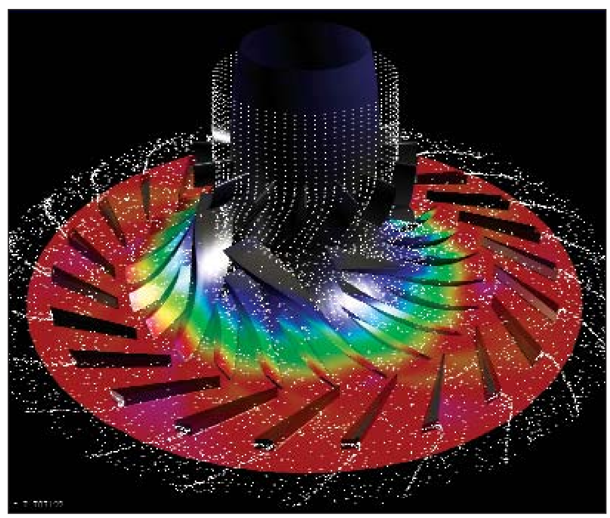
Computer simulation of a Harrier at 30 feet above the ground with a 33 Knot head wind. Red corresponds to hot temperatures and blue to cooler temperatures.

9.6 Going with the Flow

NASA researchers are developing a computational framework for design and analysis of the entire fuel supply system of a liquid rocket engine, including high-fidelity unsteady turbopump flow analysis. This capability is needed to support the design of pump subsystems for advanced space transportation vehicles that are likely to involve liquid propulsion systems.

To date, computational tools for turbopump flow design and analysis are based on relatively low fidelity methods. A tool for unsteady, three-dimensional viscous flow analysis involving stationary and rotational components for the entire turbopump assembly has not been available for real-world engineering applications.

Researchers have progressed toward a complete simulation of the turbopump for a liquid rocket engine. The Space



A snapshot of particle traces and pressure surfaces from unsteady turbopump computations.

Shuttle Main Engine (SSME) turbopump is used as a test case for an evaluation of the code. CAD-to-solution auto-scripting capability is being developed for turbopump applications. The relative motion of the grid systems for the rotor-stator interaction was obtained using overset grid techniques. Unsteady computations for the RLV baseline turbopump involved 114 zones with 34.5 million grid points. The present effort provides developers with information that will eventually lead to better designs to accommodate the propulsion impact system vibrations.

9.7 Performance Plus—New High-End Computing

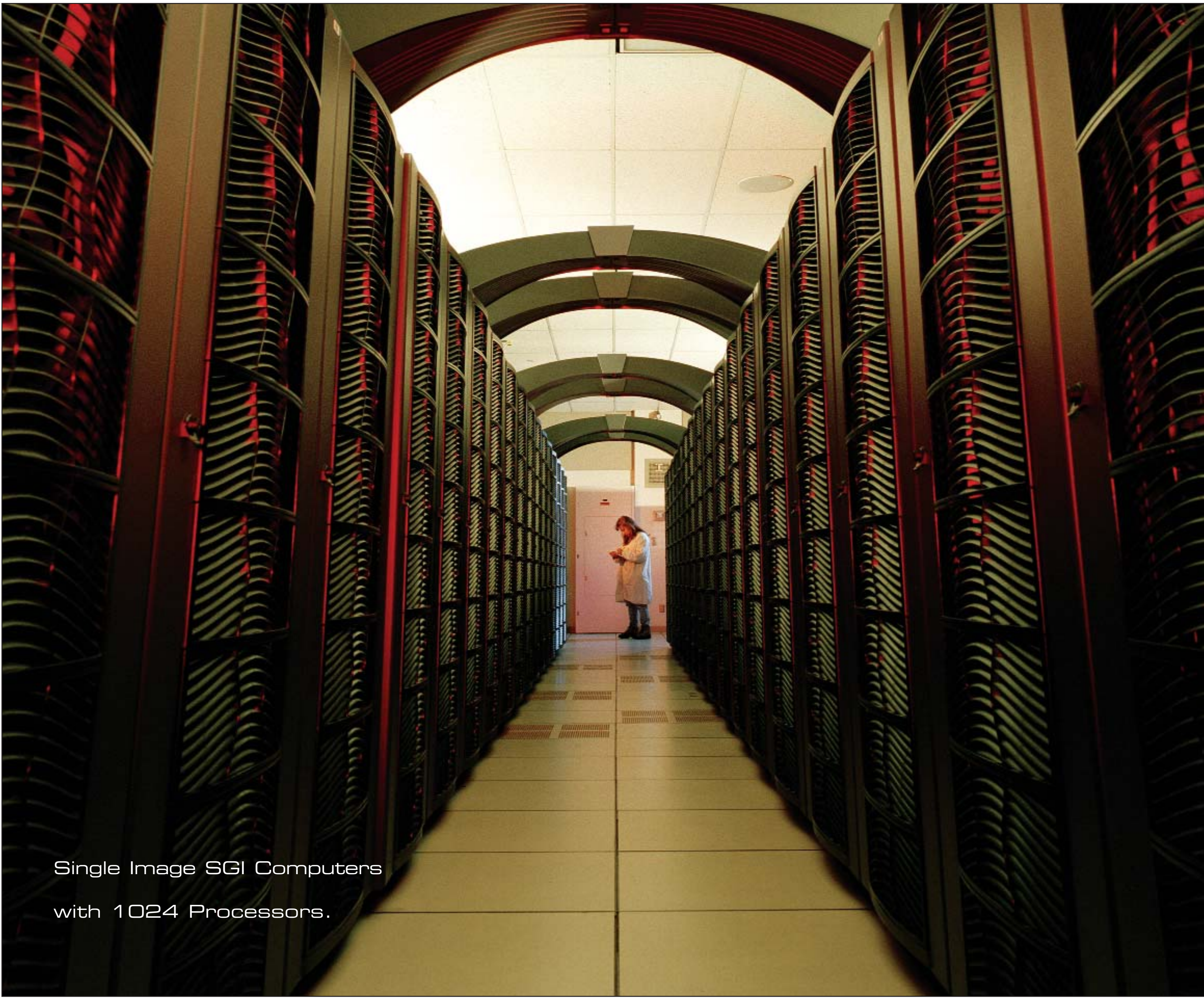
The 1,024-processor supercomputer is the largest Single System Image (SSI) supercomputing arrangement in the world. It is the culmination of five years of cooperative research and development between NASA and Silicon Graphics, Inc. (SGI). This pioneering effort allows all 1,024 processors to simultaneously work on a single problem with unprecedented efficiency, enabling a wide variety of science and engineering applications.

Significant technical advances were made in the following areas: operating systems, interconnection topology, application environment, man/machine interface, system interface, job management, hardware assembly and test, and systems testing. These advances enabled the execution of a Global Circulation Model created in a cooperative effort between NASA and the National Center for Atmospheric Research creating over 3,000 simulated days per "compute day". This type of capability will be critical as the United States reestablishes itself as the world's leader in climate research and weather forecasting.

The "1024 system" represents a new approach to high-end computing that improves performance and efficiency while reducing the complexity and cumbersome nature of parallel programming. Complex problems in aerodynamics, earth system modeling, and nanotechnology become more tractable, thereby resulting in significant reductions in both time and cost.

Objective 9: Engineering Innovation

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.



Single Image SGI Computers with 1024 Processors.

Objective 10: Technology Innovation

Enable fundamentally new aerospace system capabilities and missions.

Scientists and engineers will need cutting-edge technologies to accelerate progress and change the definition of what is possible in aerospace. NASA will aggressively explore fields with a high potential for creating advanced performance characteristics in structures and systems (e.g., information technology, biologically-inspired technology, and nanotechnology). The ability to build air and space vehicle structures and devices in new ways, perhaps atom by atom, can enable greater strength and functionality at a lower mass. New capabilities, such as self-repair of surfaces or components, automatic shape changes for optimal performance, autonomous systems, and cooperative inter-vehicle behavior, can enable safer, more reliable vehicles and systems.

10.1 Sky's the Limit

The unique Helios Prototype solar-powered flying wing, developed for NASA by AeroVironment, Inc., reached an altitude of 96,863 feet during an August 13th flight from the Hawaiian island of Kauai. Although the Helios Prototype fell short of its 100,000-foot altitude goal, it nevertheless flew higher than any previous non-rocket-powered aircraft. It also surpasses the existing altitude record of 80,201 feet for a propeller-driven aircraft, set by the Pathfinder-Plus (Helios Prototype's predecessor) in August 1998. Helios' 96,863-foot flight has been certified

It's upper surface covered by arrays of solar cells, the remotely piloted Helios Prototype flying wing soars over the blue Pacific near Kauai, Hawaii.

by the National Aeronautics Association's board of records and standards as a national record, although certification as a world record is pending.

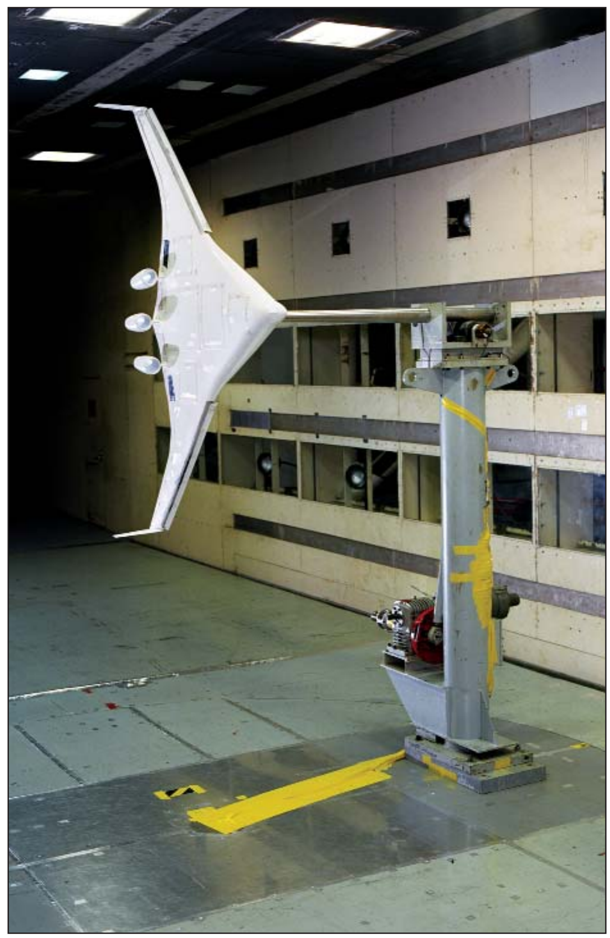
Production variants of Helios might serve as long-term environmental or disaster monitors, as well as communication relays. These aircraft would reduce dependence on satellites and provide service in areas satellites do not cover. The record-altitude flight also provided information on how and aircraft would fly in a Mars-like atmosphere, since Earth's atmosphere at 100,000 feet is similar to the atmosphere above the Martian surface.

10.2 Research for a Flying Wing

NASA is investigating advanced non-traditional vehicle designs to take advantage of the current operational airspace. The blended wing body (BWB) vehicle design has several highly desirable design benefits over conventional aircraft, like lower fuel consumption and increased passenger capacity — both of which contribute to the goal of increased mobility. In FY01, NASA researchers successfully completed the Airframe Preliminary Design Review (PDR) of the 14-percent scale BWB low-speed research vehicle, and successfully conducted a proof of concept structural test of the BWB research vehicle wing-box.

The Airframe PDR panel found the design of the BWB research vehicle outstanding and ready to move into the next phase of development. The proof of concept wing-box load test was successfully tested to failure in August 2001. It was found that failure occurred within 2 percent of the predicted load, and the craft exhibited no visible signs of degradation prior to failure. This test was significant because it validated the structural design and fabrication processes used for low-speed research vehicle.

Next steps include PDRs for the electrical and flight control systems, as well as a Critical Design Review (CDR) for the entire research vehicle. NASA's industry partner is actively seeking funds to support development of the flight control system.



A 3-percent scale Blended Wing Body model undergoing forced oscillation testing in the Langley 14x22 Foot Subsonic Tunnel.

In a field experiment on an Arctic glacier, the Cryobot successfully "drilled" 75 feel to demonstrate its application for planetary exploration.

10.3 Delivering Science on Ice

The presence of ice on extraterrestrial bodies such as Europa and Mars offers exciting possibilities for science exploration. NASA is developing a mobile science platform concept to penetrate the ice surfaces in order to better understand climate history and search for past or extant life on such bodies.

The platform, called the Cryobot, moves through ice by melting the surface directly in front of it, allowing the liquid to flow around the vehicle and refreeze behind it. As it makes its passage, optical instruments take measurements of the surrounding environment and send the collected data back to the surface lander. This method of "drilling" is more effective than conventional boring because it uses less power. A semi-autonomous steering system reduces the risk of the probe becoming entrapped by obstructions such as rocks.

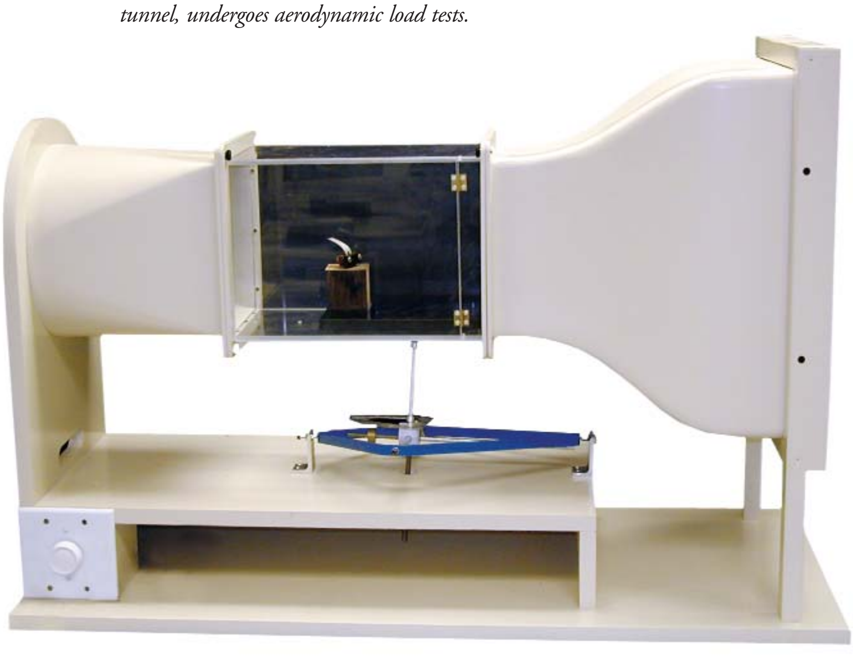
Recently, NASA teamed with the Norwegian Polar Institute and Norwegian Space Center to use the Cryobot on the island of Spitsbergen, above the Arctic Circle. This would mark the first time that the Cryobot was used on a glacier. The probe successfully melted down 23 meters (75 feet) into the glacier. The test showed that the design is a viable approach to sub-surface scientific study of *in-situ* ice for both Earth-based and extraterrestrial exploration.

10.4 Synthetic Muscles for Future Machines

Current state-of-the-art polymers are extremely limited by the degree of flexibility and strength that they can exhibit. Under the Morphing Project, NASA recently demonstrated that new lightweight graft-elastomer actuators can be custom tailored to meet design requirements.

This research began with fundamental material synthesis of electroactive polymers. The actuators were then developed by grafting on desired properties from two novel polymers, creating a hybrid material that is both strong and flexible. Finally, the actuators were evaluated under realistic aerodynamic loads in a wind tunnel. Using advanced materials synthesis, researchers were able to optimize the electromechanical properties of the polymers and achieve significant improvements in actuation strain and force. These new graft-elastomers exhibit a flexibility of 4 percent. The actuators may be used to actively control airfoils in micro-air vehicles or in micro-positioners, hingeless flaps, and flow control actuators for drag reduction. Future research includes modifying the chemical composition to improve the overall electromechanical properties of the polymer, and more rigorous evaluation of actuator performance under aerodynamic loads. Flexibility and strength testing of the actuator on an airfoil is currently underway.

An electroactive polymer, mounted in the test section of a small wind tunnel, undergoes aerodynamic load tests.

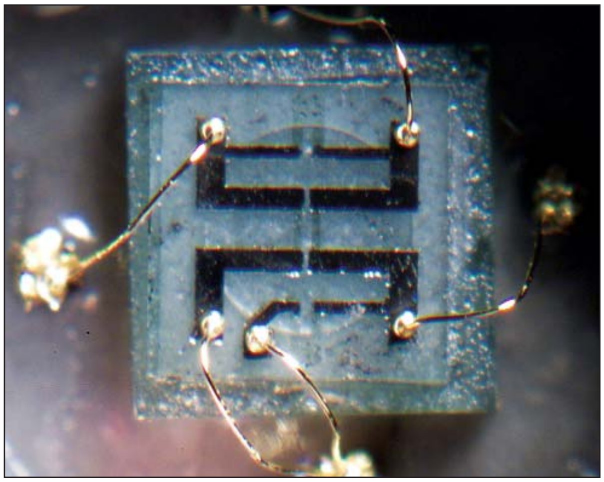


10.5 Sensing Change Where It Counts

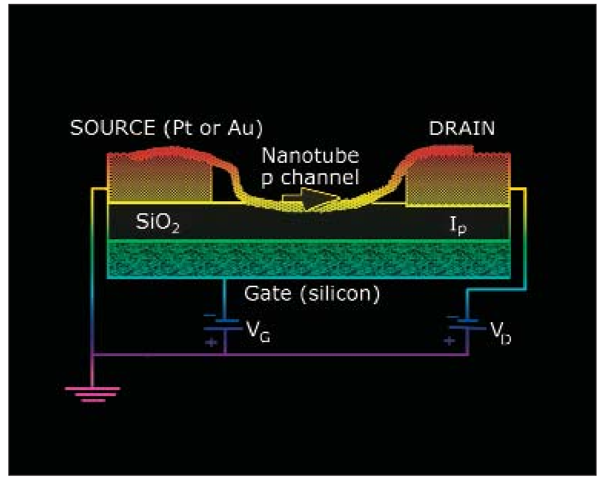
Many of today's engine systems require accurate diagnostic measurements at very high temperatures (900 degrees F and above). NASA researchers have created a High Temperature Silicon Carbide (SiC) Pressure Sensor for a fundamentally new system to monitor engine temperature. The High Temperature SiC Pressure Sensor instrumentation system allows for real-time pressure measurement and simulation in complex propulsion environments.

A small, rugged sensor was developed and installed in the compressor section of a Honeywell AS907 engine. The sensor performed successfully under conditions where the temperature reached 970 degrees F at full power. Data showed that the sensor was able to monitor pressure in the compressor during the entire test, providing critical information on compressor stall. A leadless sensor package and a hermetic seal were later developed to eliminate the fragile connection wires and to protect the metal contacts to the SiC chip. These advances increased the durability of the sensor and extended its life. Two of these new leadless sensors were tested in the P&W 4098 engine combustor, and both sensors survived the test.

The sensor will enable real-time monitoring of critical engine parameters, such as stall,



A Silicon Carbide Pressure Sensor



Schematic of a Carbon Nanotube-based inverter logic circuit.

which will lead to an improved performance margin and greater safety for air travelers.

10.6 Carbon Nanotube Field-effect Inverters

The first demonstration of an inverter logic circuit based on carbon nanotubes (CNT) is paving the way for the further development of CNT-based integrated circuits. The device structure consists of a CNT grown via a chemical vapor deposition (CVD) method and contacted by two metallic source/drain electrodes. The circuit, which uses both Complementary Metal-Oxide Semiconductor (CMOS) and Positive-channel Metal Oxide Semiconductor (PMOS) platforms, has been shown to work at room temperature. This, in turn, has important implications for electronics applications.

The CNT is a remarkable material — it can be semiconducting or metallic, and it permits the assembly of metal-semiconductors, semiconductor-semiconductor junctions. A nanotube is 1 nanometer in diameter; nanotubes can be aggregated to build "nano-scale" electronic devices. Previous methods had used various fabrication approaches to address individual single-walled carbon nanotubes. These techniques allowed the production of isolated devices such as single-electron transistors and field effect transistors. However, fabrication of integrated systems requires control of the position and orientation of the nanotubes. The recently developed CVD technique allows such control since this work exploits the advantages of small, integrated nanotube systems. The core of this fabrication approach involves depositing catalytic nanoscale iron particles onto a patterned Si/SiO_2 substrate.

This work represents a significant step toward integrated circuits based on nanoelectronic devices.

10.7 Taking a Tip From Nature

The Autonomous Formation Flight (AFF) project seeks to extend to aircraft the beneficial relationship of migrating birds flying in "V" formation. Precision formation flight

For autonomous formation control, the experimental controller was able to meet a research goal of maintaining spacing between aircraft of approximately 200 feet nose-to-tail, and 50 feet apart laterally and vertically.

allows each aircraft flying behind the lead to reduce drag and fuel consumption.

The goal is to develop flight formation technologies and demonstrate fuel savings of 10 percent during autonomous cruise flights. An autonomous station-keeping system demonstrated the ability to control the trailing aircraft at a position relative to the lead aircraft, with a discrepancy of under four feet — surpassing the project goal by about 16 feet. A piloted F/A-18 flight phase-mapped the lead aircraft's wingtip vortex effects on the trailing aircraft. Fuel flow reductions of between 14 and 20 percent were measured at the optimum formation position.

Also flight-tested was a system developed by UCLA and Boeing that uses information derived from Global Positioning System satellites and onboard systems that establish the relative position of the aircraft at an accuracy of less than 12 inches. Engineers completed the design of an autopilot that will maintain stabilized flight while positioned for drag reduction.

If AFF can make close formation a routine practice, the capacity of the air traffic system could be increased. Another benefit is a reduction in carbon dioxide and nitrogen oxide atmospheric emissions.

10.8 Reflecting on Large Telescopes

NASA's Enabling Concepts Technology Program produced a new concept that has the potential to greatly simplify the manufacture of large telescopes. The Dual Anamorphic Reflector Telescope (DART) differs from conventional telescopes in that the primary reflector is comprised of two singly-curved parabolic membrane panel reflectors, rather than a single, doubly-curved parabolic dish reflector.

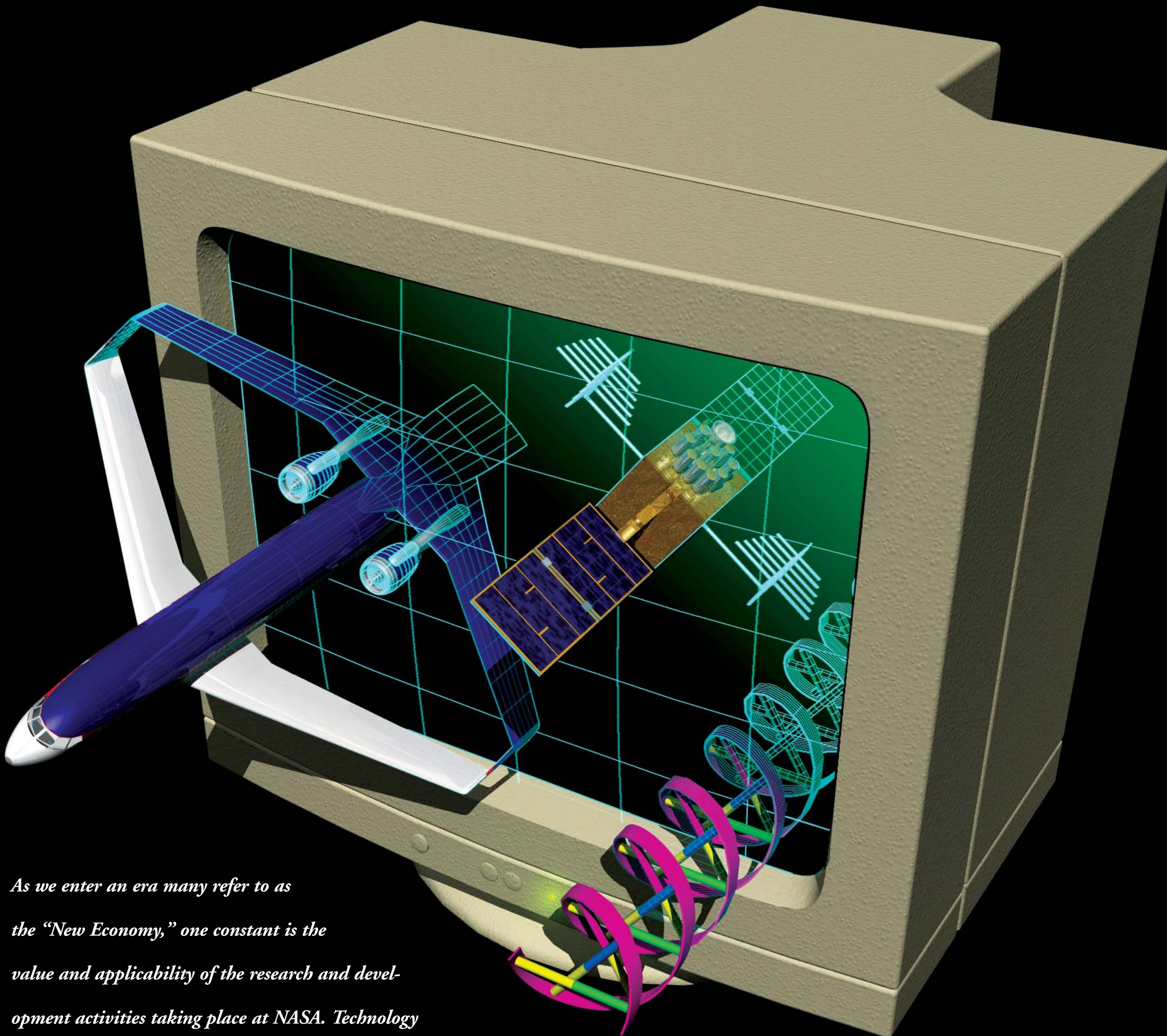
The first panel focuses incoming electromagnetic waves into a line, while the second focuses the line into the image borne by the original wave. There are several advantages to this configuration. For example, the reflector surfaces can be fabricated by bending flat panels of thin materials rather than using processes that mold, shape or grind parabolic dishes. Adaptive adjustment of reflector performance for the DART can be simplified by the use of edge controls rather than highly distributed point actuators.

The DART concept has the promise of greatly simplifying the packaging of launches, which could enable the use of large, affordable antennas that may be applied to many scientific sensing objectives for both Earth and space missions. The concept has successfully reached the proof-of-concept stage, with a laboratory model demonstrating diffraction-limited performance at infrared wavelengths.

Proof-of-concept system for a 1.2 meter dual-reflector DART telescope.

Objective 10: Technology Innovation

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.



As we enter an era many refer to as the "New Economy," one constant is the value and applicability of the research and development activities taking place at NASA. Technology developed for aerospace applications can often be beneficially applied in other industries. Whether it is NASA working in tandem with private industry, or the commercial sector turning to NASA for technological assistance, many of these aerospace technologies have found their way into new products and services. This graphic portrays the potential of commercializing NASA-developed technology into a number of applications, such as advanced aviation, medicine, and space communications.

Goal Four: Commercialize Technology

NASA's goal is to extend the commercial application of NASA technology for economic benefit and improved quality of life.

Although NASA technology benefits the aerospace industry directly, the creative application of NASA's advanced technology to disparate design and development challenges has made numerous contributions to other areas such as the environment, surface transportation, and medicine. NASA achieves this by partnering with industry as well as academia. The NASA Commercial Technology Network (NCTN) is a key mechanism for enabling technology transfer and commercialization. This network consists of the NASA-affiliated organizations across the U.S. that provide unique expertise and services to domestic enterprises and facilitate the transfer, development, and commercialization of NASA-sponsored technology. NASA will also implement activities that support internal technology transfer, to share new technologies and innovations across all NASA programs and projects as well as with other federal agencies. An effective internal and external transfer effort augments our economy, benefits the public, and fosters the leveraging of technology across NASA programs. NASA will continue to improve its technology commercialization and outreach programs to ensure the widest application of NASA-developed technology to benefit the Nation.

Commercialize Technology

Extend the commercial application of NASA technology for economic benefit and improved quality of life.

NASA technology directly benefits the aerospace industry. However, the creative application of NASA's advanced technology to disparate design and development challenges has also contributed to other areas such as the environment, surface transportation, and medicine. NASA is able to branch out by partnering with private companies both within and outside the aerospace industry, in addition to universities. These partnerships involve the full range of NASA's assets: technological expertise, new technologies, and research facilities.

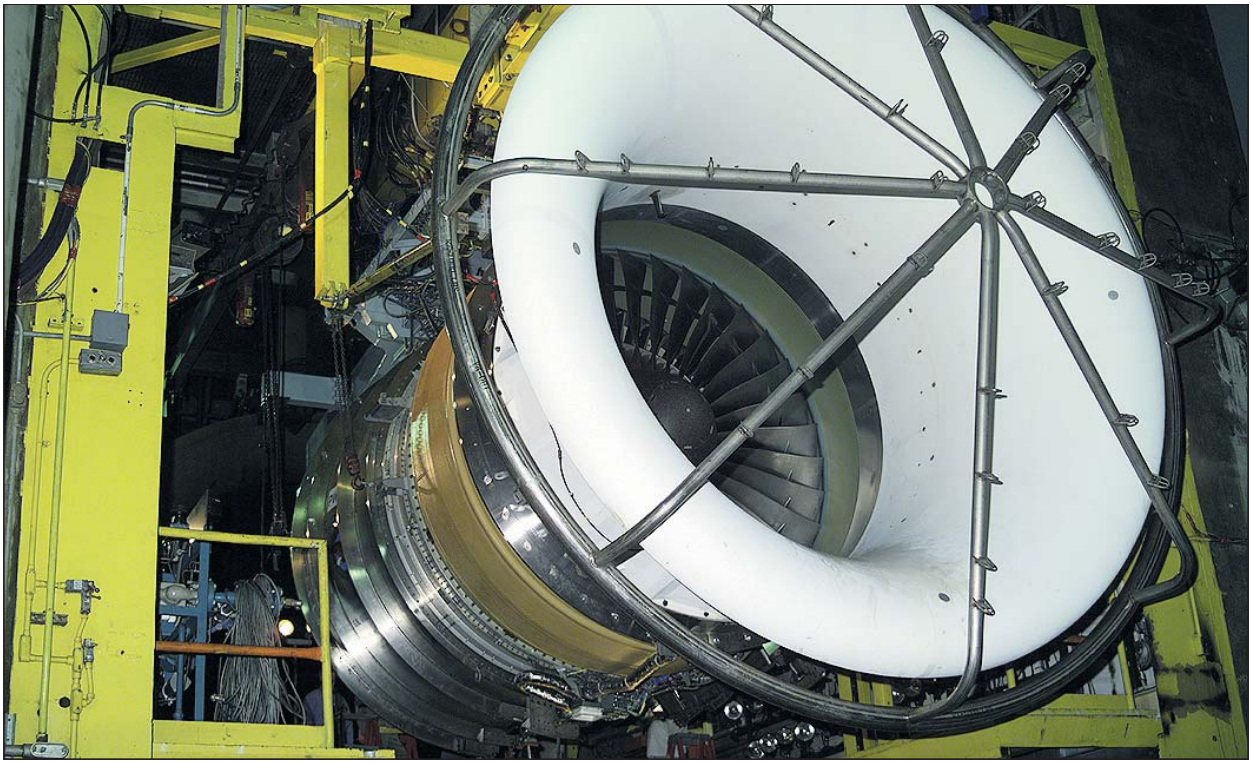
The NASA Commercial Technology Network (NCTN) is a key mechanism for enabling technology transfer and commercialization. This network consists of NASA-affiliated organizations across the U.S. that provide unique expertise and services to domestic enterprises that facilitate the transfer, development, and commercialization of NASA-sponsored technology. NASA will also implement activities that support internal technology transfer and share new technologies and innovations across all NASA programs and projects, as well as with other federal agencies.

Effective internal and external transfers helps our economy, benefits the public, and fosters technology-leveraging across NASA programs. NASA will continue improving its technology commercialization and outreach programs to ensure the widest application of NASA-developed technology.

11.1 Finding Flaws Faster NASA Scanning Technology Offers Rapid Detection

A new NASA technology can rapidly and effectively detect flaws in metals and plastics. The technology, called Scanning Thermography (ST), is able to determine the structural integrity of metals and composites by using thermal energy and an infrared imaging system. Scanning Thermography can be used to detect flaws such as disbonds, corrosion and wear in production lines, industrial tanks or piping, aircraft, power plants, and bridges. The technology has been licensed to ThermTech Services, Inc., for use in inspecting industrial boilers and tanks in a fraction of the time previously taken.

The ST system can rapidly scan and diagnose any of a number of different materials, and can be used to examine large surface areas. It is completely non-invasive and non-contacting. These scans can detect defects in conventional metals and plastics, and also in bonded aluminum, plastic, resin-based composites, and laminated structures. The ST apparatus is highly portable and scans the surface of a test material many times faster than conventional thermography or other inspection techniques. Compilation and digitization of scan images provides an inspection record that can be reviewed over time as a means of monitoring a defect within a particular structure.



Demonstration of this 50 percent NO_x reduction combustor led to a rapid commercialization of TALON combustors.

11.2 TALON "Slices" Engine Emissions

During a seven-year partnership with Pratt & Whitney, NASA was able to develop and commercialize emission reduction technology for aircraft engines by using TALON (Technology for Advanced Low NO_x) combustors. These clean-burning combustors will improve air quality around airports by reducing nitrogen oxide (NO_x) emissions from aircraft engines.

The rich-burn/quick-quench/lean-burn (RQL) low-emissions combustor concept features an initial rich-burning zone that minimizes instability and flameout, while the lean-burning zone significantly reduces NO_x emissions. The RQL concept uses fuel air atomizer-mixers and metallic liners with an advanced cooling system to achieve these major reductions in NO_x emissions during the landing and take-off cycle, as well as during high-altitude cruising, without increasing other pollutants.

This emission-reduction technology has been successfully commercialized — there are approximately 100 engines currently in service that are reducing NO_x emissions by a factor of two. If P&W manufactures PW4000 engines with the next-generation TALON II combustor, this technology will impact thousands of engines.

TEEK polyimide insulation products include variable density foams, foam-filled honeycomb and tiny microspheres.

11.3 One Formula, Multiple Forms

NASA has developed a “High-tech Insulation” that can take many forms and be made into dozens of different products. Originally developed as a high-performance structural material for spacecraft, it has low flammability with no toxic fumes, as well as several other desirable mechanical and thermal qualities. Because of this, the High-tech Insulation can be used in many ways: as a superior flame retardant for fire protection, as thermal or acoustic insulation, or to reduce structural weight.

The High-tech Insulation, called TEEK, can take the form of foam and be molded into various shapes (e.g., a honeycomb pattern, tiny microspheres, etc.). Applying TEEK as a foam during installation or repair work can result in a significant reduction in labor costs and material waste.

NASA partnered with Unitika Ltd., of Kyoto, Japan, to jointly develop and commercialize the technology. Holland, MI based SORDAL, Inc., has a non-exclusive license with NASA and Unitika to market foam products based on the technology. SORDAL plans to use TEEK as insulation for ship hulls, for fire-resistant construction materials, in various aerospace applications, and in a wide range of consumer products to improve safety and energy efficiency.

TEEK was also named one of the 100 most significant new technical products of 2001 by Research and Development Magazine.

11.4 This Picture Tells a Better Story

A new image enhancement technology developed by NASA promises to be a photographer's best friend. It will potentially improve the billions of images captured each year by low cost digital cameras, color printers, and desktop and Internet publishing programs. The technology, called Retinex Imaging Processing, was originally developed for remote sensing of the Earth by researchers at NASA and Science and Technology Corporation (STC). TruView Imaging Company, an affiliate of STC, has licensed the technology from NASA and is marketing its new software product—PhotoFlair 1.0 for home, professional and industrial use.

Using Retinex Imaging Processing, amateur photographers will be able to increase the brightness, scene contrast, detail, and overall sharpness of images. What distinguishes this technology from existing image enhancement methods is that it makes corrections automatically, yet allows the end-user to manipulate the image as desired. It won't correct every image, but was it was impressive enough to win a NASA Space Act Award as one of the agency's top Inventions of the Year for 1999.

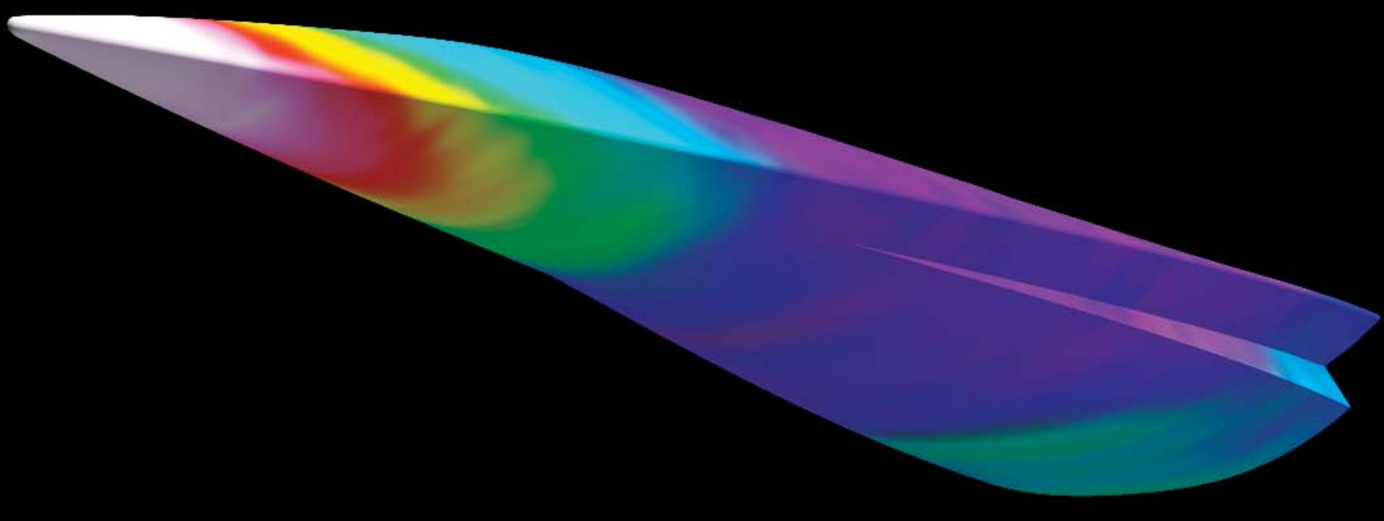
The technology is currently being refined for video image enhancement, where the technology's high-speed, automatic correcting features should make quick work of an otherwise tedious and expensive process.

Photos taken in the Virginia Air and Space Center (the official Visitors Center for Langley), show the difference before and after Retinex is applied. The left image is what the camera "sees" in the scene. The image on the right is what the eye sees after Retinex processing.

Goal 4: Commercialize Technology

The articles appearing in bold have additional images and/or information online. Check *www.aerospace.nasa.gov* for our complete report.

2001 Honors and Awards



2001 Honors and Awards

American Helicopter Society, AHS:

2001 AHS Grover E. Bell Award: To the Bell/NASA/US Army Multipoint Adaptive Vibration Suppression Systems (MAVSS) Team, given to foster and encourage research and experimentation in helicopter development.

American Institute of Aeronautics and Astronautics:

AIAA Deflorez Award for Modeling and Simulation: Richard E. McFarland, NASA Ames Research Center, in recognition of innovative technical accomplishments and leadership in real-time simulation modeling and algorithm development, especially in the areas of standardized kinematics models, time delay compensation, and rotorcraft modeling.

AIAA Air Breathing Propulsion Award: Dr. John J. Adamczyk, Glenn Research Center, for outstanding contributions in the application of turbomachinery flow modeling to turbine engine research, which resulted in major reductions in turbine engine development time and cost. This international award is presented annually for meritorious accomplishment in the arts, sciences, and technology of air breathing propulsion systems.

AIAA Dryden Lectureship in Research: David Morrison, NASA Ames Research Center. The Dryden Lectureship in Research was named in honor of Dr. Hugh L. Dryden in 1967, succeeding the Research Award established in 1960. The lecture emphasizes the great importance of basic research to the advancement in aeronautics and astronautics and is a salute to research scientists and engineers.

American Society of Mechanical Engineers:

Gas Turbine Award: Chunill Hah, Glenn Research Center, in recognition of an outstanding contribution to the literature of combustion gas turbines or gas turbines thermally combined with nuclear or steam power plants.

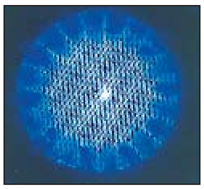
Burt L. Newkirk Award: Christopher Dellacorte, Glenn Research Center, in recognition of an individual who has made a notable contribution in tribology research or development, as evidenced by important tribology publications prior to his or her 40th birthday.

Aircraft Engine Technology Award: John J. Adamczyk, Glenn Research Center

39th R&D 100 Awards:

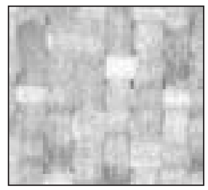
Presented annually by Research and Development Magazine, these awards honor the 100 most technologically significant new products of the year. A panel of distinguished scientists and engineers makes the selections.

TEEK: A team of researchers lead by Erik Weiser, of NASA Langley Research Center, won for a new lightweight foam insulation material called TEEK. The insulation retains its structural and insulation properties from –253 to 250 degrees Centigrade. It is non-toxic and non-fuming, has low thermal conductivity, and can be used for "in place" applications. This insulation will be of benefit for future reusable launch vehicles.



Ring Cusp Ion Engine: James Sovey, Vincent Rawlin, and Robert Roman (retired), all of Glenn Research Center, won for their innovative discharge chamber for the Ring Cusp Ion Engine. This new discharge chamber increases the useful life span of the ion engine (with reduced operating cost) by reducing the susceptibility of ion erosion in the engine and improving control of the ion flow. The ion engine is used on communication and planetary spacecraft.

Environmental Barrier Coating (EBC) for Ceramics: Materials Researchers Kang Lee, Elizabeth Opila, Cleveland State University; James Smialek, Narottam Bansal, Nathan Jacobson, Robert Miller, and Dennis Fox, Glenn Research Center; and Craig Robinson, QSS Group, Inc., for developing a multilayer coating with a corrosion-resistant topcoat. The material protects silicon-based ceramics from attack by water vapor in high-temperature combustion environments. Other development partners include GE Aircraft Engines, Evandale, Ohio, Pratt & Whitney, East Hartford, Connecticut, and Solar Turbines, Inc., San Diego, California. This breakthrough technology has paved the way for the use of ceramic components, such as combustor liners, in gas turbine engines.

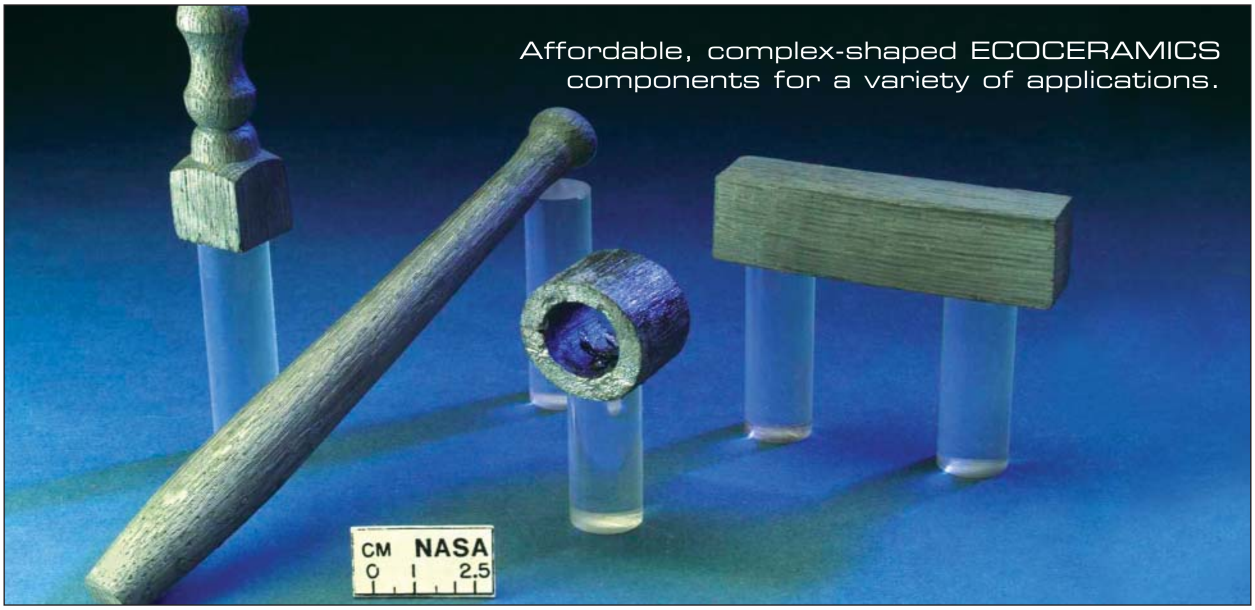


Long Lasting Silicon Carbide Fiber: Materials researchers James DiCarlo, Glenn Research Center; Hee Mann Yun, Cleveland State University; and John J. Brennan (retired), United Technologies Research Center, East Hartford, Conn., for developing a new silicon carbide fiber. The fiber has a thin, protective boron nitride coating and an internal microstructure that is more thermally stable than any other commercially available fiber. The new fiber retains its high mechanical strength after composite fabrication and during long-term service under high-temperature oxidizing conditions.

Aluminum-Lithium Alloy 2098: A team of Researchers from NASA Langley Research Center, McCook Metals LLC, and Lockheed Martin Aeronautics Company developed a new low-density, high strength and high fracture toughness alloy that will enable affordable and maintainable supersonic aircraft. The new alloy is capable of meeting the demanding requirements of Mach 2+ supersonic aircraft.

Ecoceramics: A team of Researchers from NASA Glenn Research Center and Dynacs Engineering Co. Inc. have developed a new process that will produce a new class of environmentally-friendly ceramics. Mrityunjay Singh, QSS Group, Inc., who works in the Glenn Research Center

Above Left: Discharge chamber eliminates erosion sites. Below Left: Processing of NASA EBC by high-temperature plasma spraying. Right: Woven Sylramic™ fiber can be used to make ceramic composites



Materials Division, calls his winning product "ecoceramics," because it starts with a renewable resource—wood or wood byproducts such as sawdust. The wood is fabricated by pyrolysis into preforms, which are then infiltrated with molten silicon or silicon alloys. The result is a strong, tough, low-cost alternative to traditional ceramics.

14th Annual "The Best of What's New":

Announcements by Popular Science Magazine to celebrate the 100 most important innovations in products and technologies of the year, and to honor the spirit of ingenuity that brought them into being.

Helios: For achieving the world altitude record for non-rocket-powered aircraft, formerly held by the Air Force's SR-71 Blackbird. The unmanned Helios, developed by a NASA/AeroVironment partnership, averaged 25 miles per hour as it climbed to 96,500 feet. Helios exceeded the SR-71 record by 10,000 feet.

I-2000 Inflatable Wing: During flight a nitrogen canister inflated the I-2000's 32-inch long wings in a third of a second. It marked the first time an aircraft's wings have ever been inflated in flight. The I-2000 is a NASA plane that may someday be dropped form spacecraft orbiting other planets.

Enterprise employees are honored each year by their peers through advanced membership grades in professional societies.

AIAA Fellows:

Each year, the AIAA conscientiously surveys the aerospace field to identify practitioners who have made notable and significant contributions.

- John W. Edwards, Langley Research Center (Retired)
- Carolyn S. Griner, Marshall Space Flight Center (Retired)
- Banavar Sridhar, Ames Research Center

NASA Centers

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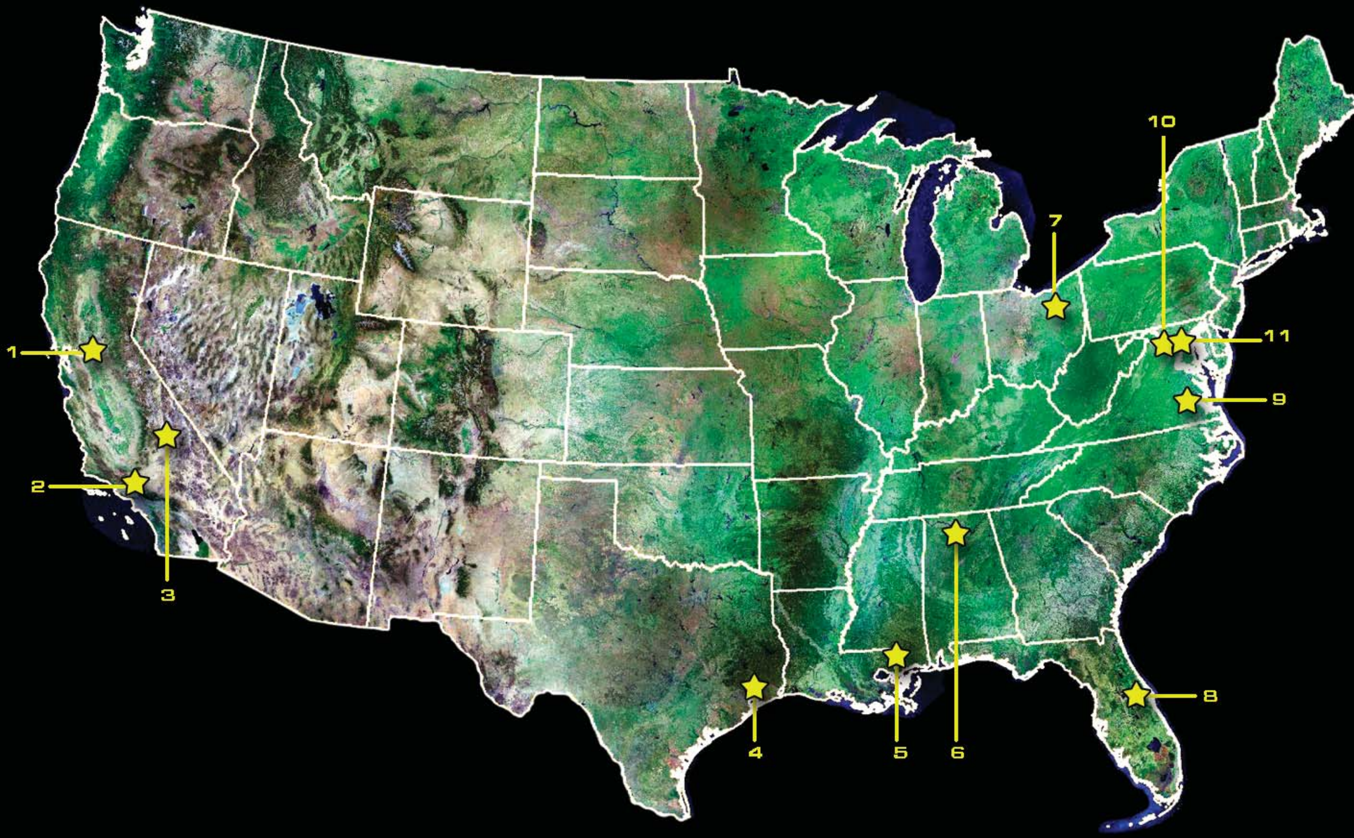
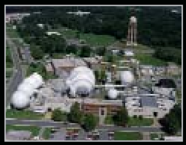
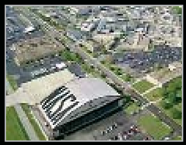
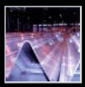
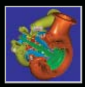
1. Ames Research Center
2. Jet Propulsion Laboratory
3. Dryden Flight Research Center
4. Johnson Space Center
5. Stennis Space Center
6. Marshall Space Flight Center
7. Glenn Research Center
8. Kennedy Space Center
9. Langley Research Center
10. NASA Headquarters
11. Goddard Space Flight Center



Enterprise Field Centers

	Ames	Dryden	Langley	Glenn	Marshall
					
Mission	 *Aviation Operations Systems*	 *Flight Research*	 *Airframe Systems and Atmospheric Systems*	 *Aeropropulsion*	 *Transportation System Development*
Center of Excellence	 *Information Technology*	 *Atmospheric Flight Operations*	 *Structure and Materials*	 *Turbomachinery*	 *Space Propulsion*

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Ames Research Center
Moffett Field, CA 94035-1000
Directory Information: 650-604-5000

Dryden Flight Research Center
Edwards, CA 93523-0273
Directory Information: 661-276-3311

Glenn Research Center at Lewis Field
Cleveland, OH 44135-3191
Directory Information: 216-433-4000

Langley Research Center
Hampton, VA 23681-2199
Directory Information: 757-864-1000

Marshall Space Flight Center
Marshall Space Flight Center, AL 35812-0001
Directory Information: 256-544-2121

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Washington, DC 20546

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